Brit. J. Ophthal. (1952) **36**, 225.

COMMUNICATIONS

STEREOSCOPY—AND A NEW STEREOSCOPE*

BY

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IN the belief that further discussion and fuller understanding of the optics, functions, and application of the stereoscope are needed, it has been thought justifiable to enter more deeply into the questions of stereoscopy in general and of stereoscopic exercises in particular.

The function of a stereoscope is to present two different images of the same object simultaneously to the two eyes. This can be achieved merely by holding two pictures of the object in front of the eyes at a distance at which clear images can be received; the exercise usually needs practice, and is artificial in that convergence, which usually accompanies accommodation, is not called into play. The model stereoscope here presented eliminates this artificiality by the action of the base-out prisms which it incorporates (Fig. 1); it further allows close approximation of the pictures to the eyes by providing convex lenses which supplement accommodation.

It would appear, however, that the strength of lenses and prisms is chosen in a haphazard fashion, and the relationship between accommodation and convergence is left to chance; further, as has been previously shown (Law, 1948), the effect of moving the object cards nearer to or farther away from the eyes is also fortuitous. It is obviously desirable that the instructor should be in possession of full data concerning instrument and patient so that he may know just what effect any manipulation will bring about.

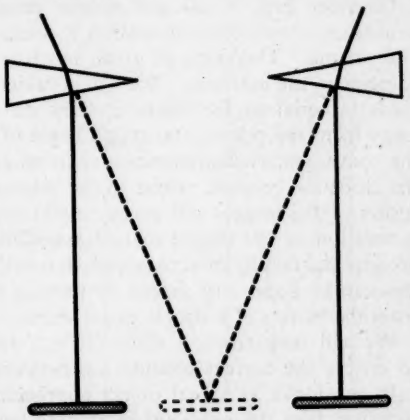

FIG. 1.—Action of base-out prisms in a simple prism stereoscope.

The optical part of a stereoscope may be partially or completely neutralized, and it is then interesting to note the effect on the impression gained and the manipulations which can be undertaken both by a youngster with a wide range of accommodation and by a presbyopic adult. On viewing, say, a card

* Received for publication November 22, 1951.

from the H series of Wells's charts on which the diagrams are chosen to be approximately at the same distance apart as the pupils, a child may suffer no loss of effect with no lenses or no prisms. When both are neutralized, the result is merely to limit the approximation of the card towards the eyes. Similarly, most adults find no difficulty in dispensing with the prisms; neutralization of the lenses prevents near approach to the usual range, and elimination of both prisms and lenses makes it necessary to hold the card at an inconvenient distance beyond the range of the normal stereoscope. The stereoscopic effect produced by the same card used in the normal fashion in the same instrument may differ radically between the two subjects.

The ideal stereoscope should enable the operator to exercise accommodation and convergence, separately or together, in their normal relationship, or in any chosen relationship.

The Split-Lens Stereoscope

Fig. 2 shows that one half of a convex lens is equivalent to a prism to each face of which has been added a plano-convex lens. We have seen that each eye-piece of a stereoscope consists of a prism + a convex lens. It is often more convenient to look upon this as a prism + two plano-convex lenses, that is to say, as one half of a biconvex lens. This greatly simplifies many of the calculations, and is the method used by Brewster who originally devised the lenticular stereoscope.

In problems concerning squint and latent squint, one of the chief considerations is the relationship between convergence and accommodation. Law (1948) has shown that it is precisely in this respect that existing stereoscopes are defective.

Consider first of all the simple prism stereoscope. The relation between convergence and accommodation is correct only for one distance between cards and prisms. The angle of prism must be such that the two images of the cards coincide in the mid-line. We will consider the case when the distance between the cards is equal to the inter-pupillary distance. If the cards are moved further away from the prisms, the actual angle of convergence remains the same, that is, the convergence becomes excessive in relation to the accommodation (Fig. 3*a*). If the cards are brought nearer to the prisms, the angle of convergence required for fusion of the images will again remain constant, and will thus become too small in relation to the degree of accommodation (Fig. 3*b*). Should it be required to exercise the faculty of accommodation without changing the angle of convergence, this can be done very simply by moving the cards alternately towards and away from the prisms of a simple prism stereoscope.

We will now consider the split-lens stereoscope and the conditions necessary to ensure the correct relationship between convergence and accommodation.

If one looks at a real object approaching one's nose from infinity along the mid-line, then the relationship existing between accommodation and convergence is the correct or normal relationship. It follows that the requirement for a stereoscope is that the images of the two pictures shall coincide in the mid-line and shall approach the observer from infinity. We will use this as a basis from which to calculate the required locus of the card centres.

The construction is shown in Fig. 4. First draw a large lens of the same focal length as the stereoscope lens and with its centre in the same position. Let this lens be large enough to be cut by the mid-line, ID. Consider any one position of

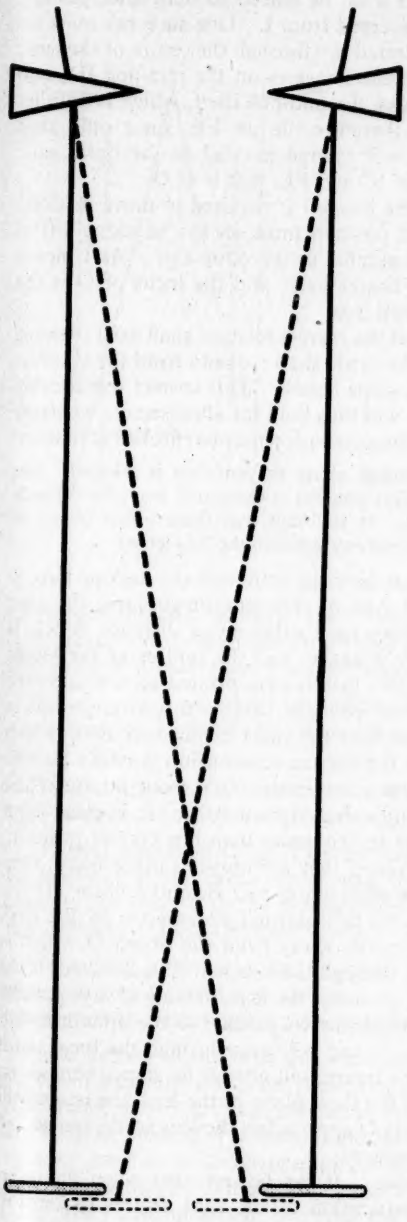

FIG. 3(*a*).

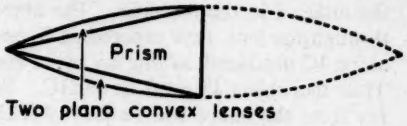

FIG. 2.

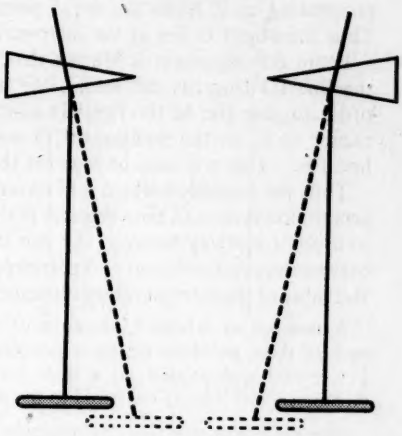

FIG. 3(*b*).

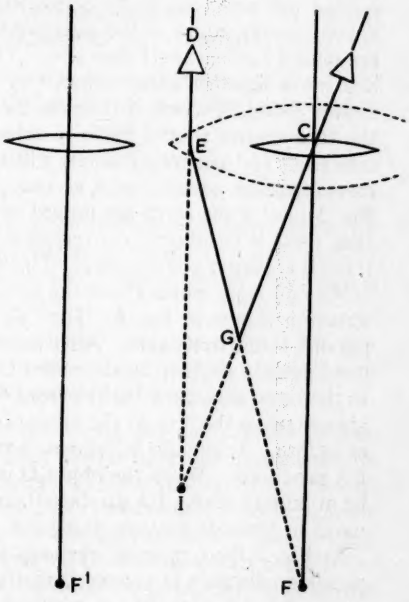

FIG. 4.

the image I in the mid-line. The object G must be placed so that, after passing through the lens, rays proceed as if they diverged from I. One such ray must lie along IC produced, as this ray is the undeflected ray through the centre of the lens. Thus the object G must lie on IC. Since the image is on the mid-line ID, one ray from the image will be the ray IED along the mid-line itself, which is parallel to the optic axis. The object G must, therefore, lie on FE, since only rays proceeding as if from the focal point F will emerge parallel to the optic axis. Thus the object G lies at the intersection of IC and FE, that is at G.

From this argument it follows that, as the image I is required to move in along the line ID towards the lenses, the object position must always lie along FE in order to give rise to the ray ED which is parallel to the optic axis. As I moves nearer to E, so the position of G moves nearer to E, and the locus of G is the line FE. This will also be true for the small lens.

Thus the condition which will ensure that the correct relation shall exist between accommodation and convergence is that the cards shall move in from the two foci to a point midway between the two stereoscope lenses. This correct relationship between accommodation and convergence will thus hold for all observers whatever the value of the interpupillary distance. This conclusion may be checked as follows:

A number of arbitrary positions of the image along the mid-line is selected. For each of these positions the corresponding object position is calculated from the formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ and plotted on a scale drawing. It is found that these object points all lie along a line joining the focus to the point midway between the two lenses.

We may now use this construction to see how the orthodox stereoscope fails to produce the correct effect. In the usual type of split-lens stereoscope, the card centres are arranged to be separated from each other by a distance which is approximately equal to the interpupillary distance, and the centres of the lenses are placed further apart than this. The two pictures are printed on a single card and move together either towards or away from the lenses; this arrangement is shown in Fig. 5, which also shows the two lines FE and F^1E, the loci along which the card centres should move to achieve the correct relationship between accommodation and convergence. It will be seen that each actual locus intersects the corresponding correct locus at one position only (point $0,0^1$). It is clear from Fig. 5 that, if the cards are moved nearer to the lenses than this correct position, then there is insufficient convergence, while, if they are moved further away, then there is excessive convergence. This was pointed out by Lyle and Jackson (1949).

We can learn more about the conditions in a normal stereoscope by the construction shown in Fig. 6. Here we consider a ray from the object O which is parallel to the optic axis. After passing through the lens it will be directed to the focal point. Further, as the object O approaches the lens, moving always parallel to the optic axis, then the ray from O which travels parallel to the optic axis will always strike the lens at the same point A, and will pass through the focal point as before. From this it follows that the image will always lie somewhere along FA produced. When the object O is in the focal plane of the lens, the image will be at infinity (along FA produced), and as O approaches the lens so the image will move in towards the lens along FA produced.

In Fig. 5 three pairs of eyes are shown. It can be seen that when the interpupillary distance is greater than the separation of the card centres (outermost pair), then as each image moves in along FA produced, the eyes, which are

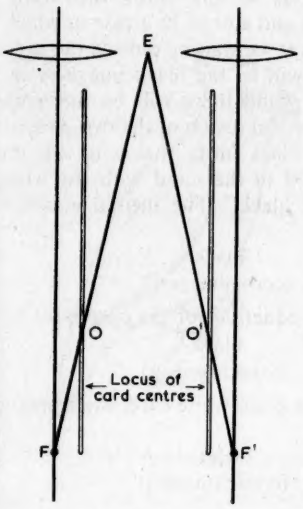

FIG. 5.

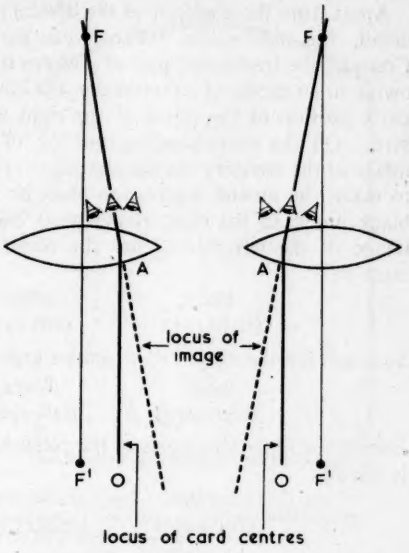

FIG. 6.

converged initially, increase their convergence slightly as the cards approach. The previous discussion has shown that this increase in convergence is insufficient, and leads to a deficiency of convergence in relation to the accommodation.

If the eyes are separated by a distance which is equal to the separation of the cards, then the angle of convergence is not changed as the cards approach (middle pair of eyes).

Finally, if the eyes are separated by a distance which is less than the separation of the cards, then the eyes converge less, *i.e.*, relatively diverge, as the cards approach.

The first treatment (Fig. 5) shows that, with the conventional stereoscope, for all positions of the cards except one, there will be an excess or a deficiency of convergence relative to the accommodation, and that this excess or deficiency is not dependent upon the interpupillary distance.

The second treatment (Fig. 6) shows that whether an approach of the card causes an actual increase or decrease in the angle of convergence depends very much upon the interpupillary distance, as was shown by Law (1948).

These defects in the orthodox stereoscope must have two unfortunate results. Firstly, if exercises on it are prescribed by people who have not appreciated its limitations, these exercises may not be appropriate to the condition of the patient. Secondly, as a result of inappropriate exercises being prescribed it becomes harder to make progress in understanding the nature of convergence defects and devising suitable treatments. These remarks apply only to the stereoscope and not to the many other instruments in common use for diagnosis or treatment, such as the synoptophore, the Rémy separator, the Maddox wing, and the Maddox rod.

Apart from these defects of the optical system, which we have discussed in some detail, the stereoscope suffers from further defects in the cards themselves. Consider the traditional pair of pictures of a parrot and a cage, in a case in which, owing to an excess of convergence, the bird appears to be waiting outside the cage. On a portion of the retina of the right eye there will be the black image of the bird. On the corresponding portion of the left retina there will be the white image of the territory outside the cage. For a successful fusion of the two pictures to occur the mental impression must be one of a black bird; that is to say, the black image of the right retina must become fused in the mind with the white image of the left retina, and the result must be black. The mental equation must be:

$$\underset{\text{(right eye)}}{\text{black}} + \underset{\text{(left eye)}}{\text{white}} = \underset{\text{(consciousness)}}{\text{black}}$$

So much for the bird. By a similar argument the equation for the cage must be:

$$\underset{\text{(right eye)}}{\text{white}} + \underset{\text{(left eye))}}{\text{black}} = \underset{\text{(consciousness)}}{\text{black}}$$

For all the remaining parts of the picture which are plain white card, the equation is merely:

$$\underset{\text{(right eye)}}{\text{white}} + \underset{\text{(left eye)}}{\text{white}} = \underset{\text{(consciousness)}}{\text{white}}$$

It is very remarkable that the mind can in fact solve these equations, and solve them quite easily. The subject of binocular mixtures of black and white was very thoroughly studied by Panum (1858) who showed that equations of the above type can readily be solved under appropriate conditions. What these conditions are is best illustrated by the experiment of the black cross, which is fundamentally the same as that of the parrot and cage. A vertical black bar is seen by the left eye, and a horizontal black bar by the right eye; the interruption of continuity of the black bars at the crossing is a well-known phenomenon.

The principle underlying these fusions is that in the neighbourhood of a black area the surrounding white area is emphasized and tends to prevail in the fused mental picture. Thus, in the case given above, the vertical bar is surrounded by an emphasized white, so that in the fused picture it carries this white across the middle of the horizontal bar. In a similar way the horizontal bar carries an emphasized white across the vertical bar. The situation is further complicated by the fact that the black is also emphasized by the white, with the result that rivalry occurs at the area of intersection. It would be a mistake to pursue this theoretical aspect too far. From a practical point of view, in order that fusion of black and white pictures may be easy, it is necessary that in the mental picture the black portions seen by the left eye must not come too near to the black portions seen by the right eye. In the case of the parrot and the cage the simultaneous perception is easy if the bird remains outside; however, the object of this exercise is to get the bird into the cage, and it is precisely here with the bird behind the bars that the mental equations become hardest to solve. Had the designer of the card wished to make the task as hard as possible, he could not have done better than draw black bars all over the cage, as he has in fact done, thus emphasizing the white areas which have to be suppressed in the region of the image of the black bird before success can be achieved.

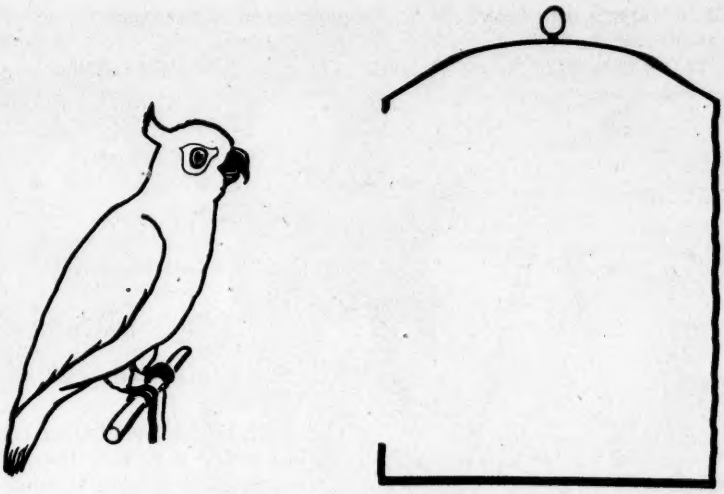

FIG. 7.—Parrot and cage picture in which, in the fused mental image, there is no crossing of lines from the one picture by lines from the other. This minimizes rivalry. The bird may with advantage be drawn smaller than the one shown here.

It would be sad to break with tradition to the extent of abandoning the bird and the cage. As much as possible must be saved but the bars must go, and it is advisable for the cage to be open in the front. Since the bird is supposed to enter the cage, this is reasonable on grounds of common sense. A diagram of a parrot and cage which avoids the defects described is shown above in Fig. 7.

Summing up, we may say that the familiar type of stereoscope allows no control over the relationship between convergence and accommodation, and that it demands from the patient the performance of mental gymnastics far more difficult than any he needs to perform in the course of everyday life. One must not, however, fail to acknowledge that many modifications of the original stereoscope have been designed and produced, with different objects in view. A particularly ingenious model, designed by Hudson (1918), consisted of two bars carrying prisms at one end and object-diagrams at the other. A slot traversed the longitudinal axis of each bar and also that of a central bar; the inclination of the two bars to each other was determined by the position of a vertical pin which could be moved towards and away from the observer. A screen carried on the central bar could be converted by a hinge movement from a central obturator to two lateral obturators with a central aperture, which action, combined with a suitable adjustment of the prisms, determined which object-diagram was viewed by which eye. The capabilities of this instrument are many, and the range of convergence and divergence which can be induced is vast, but accommodation is not exploited. It is apparently not possible to obtain such an instrument to-day.

Other important modifications were described by Krimsky (1937, 1941), who is also dissatisfied with the usual type of lens-prism stereoscope; his instruments are familiar to all interested in the subject.

The instrument here described* has been designed to overcome the errors and limitations discussed above, and every effort has been made to keep it as simple as possible. It consists of three parts: the two lenses, the two rails, and the two cards which slide along the rails (Fig. 8). The two large 5-dioptre lenses are held in a plate, so that the distance between their centres is 80 mm. The diameter of each lens is 43 mm. Interpupillary distances will not have values outside the range 50 to 70 mm.; consequently, for any pair of eyes only the inner half of the lens will be used (Fig. 9). This part of the design is the same as in normal stereoscopes.

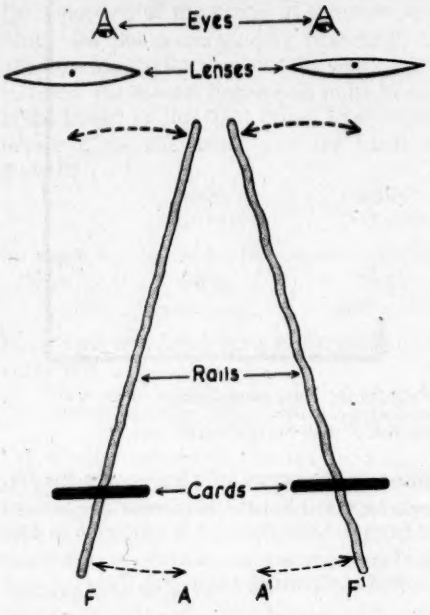

FIG. 8.—Essential components of new stereoscope, namely the two lenses, the two rails, and the two cards which slide along the rails. The separation of the near and far ends can be varied independently.

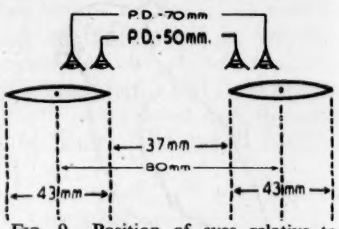

FIG. 9.—Position of eyes relative to lenses for large and small interpupillary distances.

The rails (Fig. 8) are arranged so that they can occupy a great variety of positions. The ends of the rails remote from the lens can occupy any position between F—A and F′—A′, F and F′ being the foci of the lenses. It is arranged that the ends of the rails always move symmetrically outwards and inwards together. The near ends of the rails are adjustable between positions opposite the lens centres and the position of contact in the mid-line.

The cards (Fig. 8) are carried in holders which can be slid backwards and forwards along the rails. Each card-holder is quite separate from the other, but it is so arranged that they slide along the rails so that each is always the same distance as the other from the plane of the lenses. They slide thus no matter at what angle the rails may be inclined to each other.

A photograph and a perspective drawing are shown in Figs 10*a* (opposite) and 10*b* (overleaf). The fixed portion consists of the plate holding the lenses, with cells for additional prisms, the near bar supporting the near ends of the rails, the middle rail bolted to this near bar, and the handle which folds for convenience in packing. The near ends of the adjustable rails may be fixed by lock-nuts at any position on the near bar; their separation is shown by a scale marked on the bar.

* Our thanks are due to Mr. Holland of the Chad Valley Company who most generously worked out almost the whole of the mechanical design, as well as to Keeler Optical Products, Ltd., for their initiative in developing the final prototype.

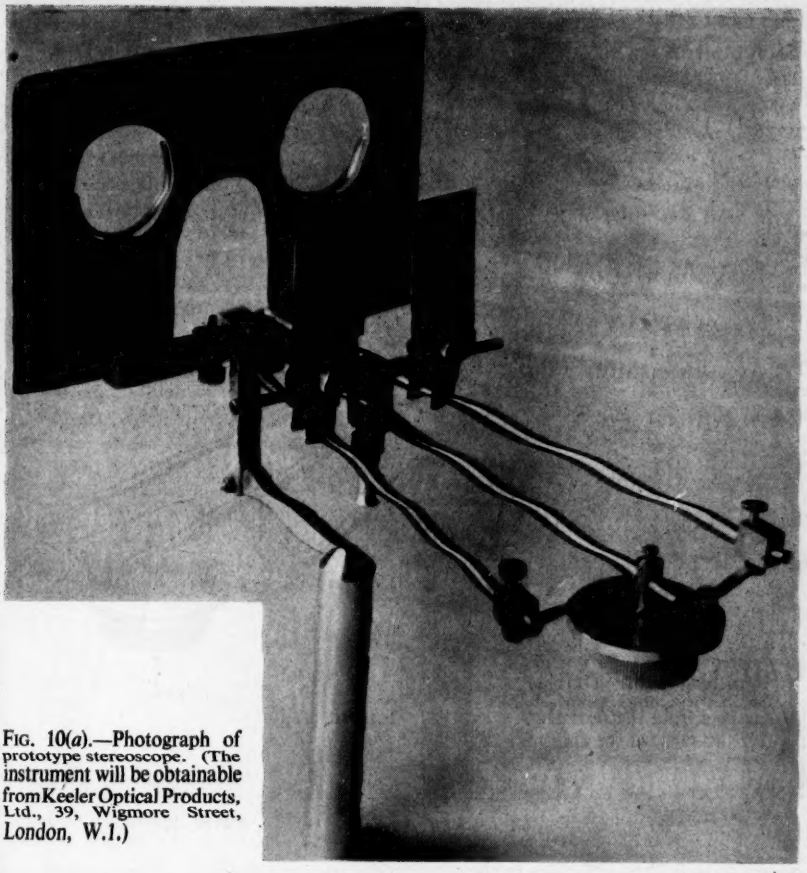

FIG. 10(*a*).—Photograph of prototype stereoscope. (The instrument will be obtainable from Keeler Optical Products, Ltd., 39, Wigmore Street, London, W.1.)

The far end of this middle rail carries a wheel connected by pivot arms to the far ends of the rails. Rotation of this wheel moves the far ends of the rails inwards or outwards. The middle rail is marked to indicate the dioptres of accommodation required to view the cards at each point. No facilities are included for vertical exercises, as these are generally considered valueless. If, however, horizontal exercises are to be given to a patient whose defect includes a vertical component, then a 'base-up' or 'base-down' prism may be placed in front of one of the lenses.

A description of the mechanism for the movement of the card-holders may be difficult to grasp without seeing the instrument itself. Free to move up and down the fixed middle rail there is a sliding box (Fig. 10). Rigidly attached to this box is the cross-bar. By means of the small handle shown, the sliding box may be moved along the middle rail, and as it moves it carries with it the cross-bar, which always remains perpendicular to the fixed middle rail. At each end the cross-bar

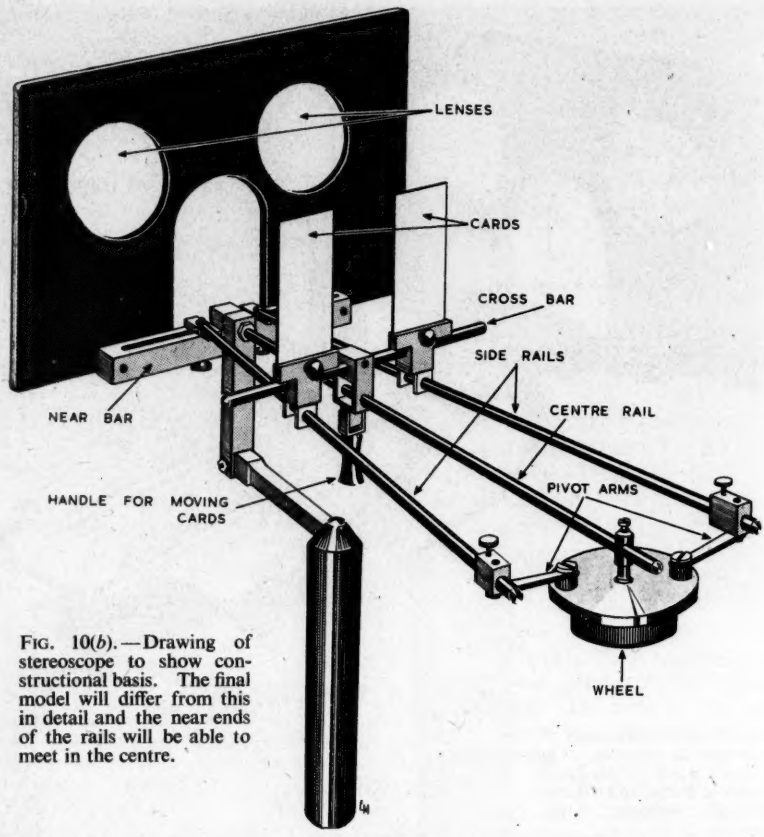

FIG. 10(*b*).—Drawing of stereoscope to show constructional basis. The final model will differ from this in detail and the near ends of the rails will be able to meet in the centre.

passes loosely through holes in the support for the card-holders. Each card-holder support is free to move along the side rails, so that the card-holders are carried along the side rails as the sliding box is moved along the fixed middle rail. If the side rails are set at an angle to each other this motion results in some movement along the cross-bar as the card-holders approach or recede from the centre line.

The supports for the card-holders are made in two halves, top and bottom; it is arranged by means of a loose rivet joining the two halves together that the top half is free to rotate separately about a vertical axis. This is necessary because the side rails change their angle of inclination to the cross-bar.

THE STEREOSCOPE IN USE

Let us now see how this stereoscope can be used to exercise convergence only, accommodation only, the two in the normal relationship, or the two in other relationships.

EXERCISE 1. CONVERGENCE ONLY WITH ACCOMMODATION RELAXED (Figs 11*a* and *b*).

The near ends of the rails are kept fixed in any position. The cards are placed at the far end of the rails, which brings them into the focal plane of the lenses. When the ends of the rails are maximally separated, the centre of each card is at the focal point of the lens. In this case, rays from a point in the centre of each card will emerge from the lens parallel to the optic axis (Fig. 11*a*). Thus the visual axes will be parallel. If the observer directs his eyes to see, say, a portion of the card to the left of the centre, the rays will emerge from the lens parallel to each other. The direction of this parallel bundle is given by a line drawn from the point on the card in question through the centre of the lens (Fig. 11*b*). It is clear that the visual axes will be parallel to each other, no matter which portion of the card is viewed, and no matter what is the value of the interpupillary distance. When the cards at the ends of the rails are moved inwards the visual axes converge. With the cards in the extreme inwards position the angle between the two visual axes is 16°, which is the angle adopted by an observer with a pupillary distance of 56 mm. when observing an object at a distance of 20 cm. and thus using a 5-dioptre effort of accommodation.

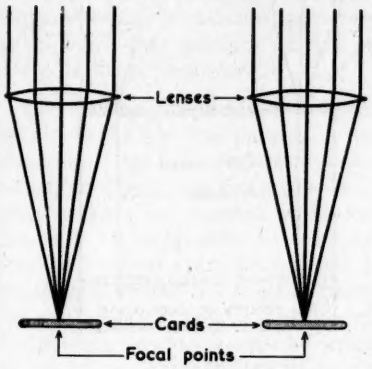

FIG. 11(*a*).

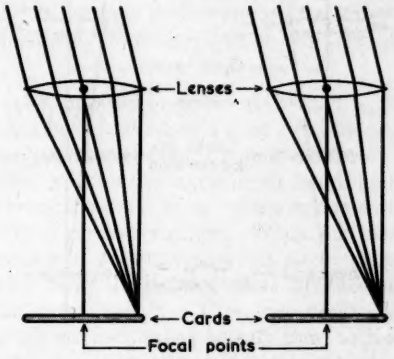

FIG. 11(*b*).

In order to exercise convergence with the accommodation completely relaxed, the patient moves the cards until they are at the ends of the rails, that is, in the focal plane of the lenses. He then turns the far wheel first one way and then the other, so as to move the cards in and out slowly enough for fusion to be maintained. Again, if the cards are moved a little way towards the lens, the image of the card will move from infinity towards the eye, and some accommodative effort will be required. If this is done and the far ends of the rods are again made to move in and out, convergence will again be exercised while accommodation remains steady. This exercise may be repeated for a number of positions of the cards along the rails, and convergence may thus be exercised while the accommodation remains at any one of a number of fixed values.

EXERCISE 2. ACCOMMODATION ONLY WITH ANGLE OF CONVERGENCE UNCHANGED.

The cards are placed at the far ends of the rails which are separated to their full extent, thus bringing the centre of each card to the focal point of the lens. All

rays from the card centre will emerge from the lens parallel to each other and to the optic axis. Only one such ray, that which enters the pupil centre, has been drawn (Fig. 12). The near ends of the rails are now so placed that they lie immediately under and parallel to this ray. This condition is achieved in practice by adjusting the position of the near ends of the rails so that their extensions cut the plane of the lenses in two points separated by a space equal to the interpupillary distance. The patient's interpupillary distance is measured, and he is told how to place the pointers. He now draws the cards towards him along the rails. Consider the card centres when the cards have moved some way along the rails to the point labelled " second position " in Fig. 12. After passing through the lens, the rays will diverge; notice that one ray will travel over its previous path, emerge parallel to the optic axis, and enter the centre of the pupil.

Thus, as the cards approach the observer, the eyes will accommodate for the nearer distance of the images, but the visual axes will always remain parallel.

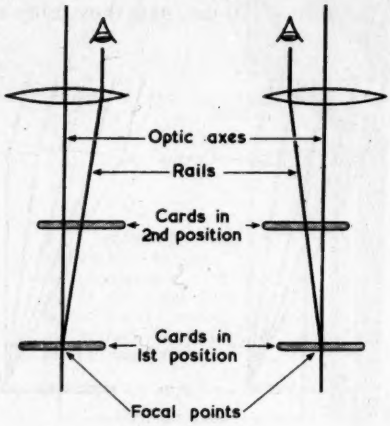

FIG. 12.

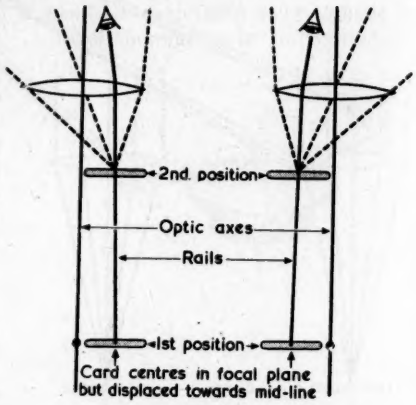

FIG. 13.

The experiment may now be repeated so as to maintain an angle of convergence fixed at some definite value, while the accommodation is continuously varied. To do this the far ends of the rails are made to approach each other, and the cards are again made to approach the observer. Rays from the card centres are drawn for two positions of the card (Fig. 13); it is clear from the diagram that, in the second or nearer position, the ray that enters the pupil centre must travel over its previous path and that therefore the angle of convergence of the eyes does not change. The accommodation must of course change as the image moves in from infinity.

EXERCISE 3. ACCOMMODATION AND CONVERGENCE IN NORMAL RELATIONSHIP.

We have shown (Figs 3*a* and *b*, p. 227) that, if the card centres move along a line joining each focus to the point midway between the two lenses, then the images of the two cards are superimposed and move in towards the observer from infinity

along the mid-line. To perform this exercise, the far ends of the rails (which are in the focal plane of the lenses) are moved to the fully extended position, so that the card centres are at the focal points. The near ends are adjusted so that they meet in the mid-line in the plane of the lenses. The cards are now moved backwards and forwards sufficiently slowly for fusion to be maintained.

It may be asked what advantages this exercise possesses over that of looking at one's thumb and moving it to and fro without using a stereoscope at all. There are two: firstly, the image can be moved to infinity, and secondly, it is possible, by the use of suitable cards, to make sure that both eyes are being used the whole time, whereas when using the thumb it is very difficult to tell when suppression occurs.

In using this instrument, however, one surprising result is found. If the cards are placed at the ends of the rails (in the focal plane of the lenses), and their distance apart is adjusted until fusion occurs most easily, nearly all observers will move the cards well in towards the mid-line, thus inducing an angle of up to 16°. Since the image is at infinity this seems at first surprising, but it is nevertheless very marked. Furthermore, most normal orthophoric observers experience a considerable sense of strain in moving the cards out until the visual axes are parallel. They find this eye exercise hard work, yet they are only performing an eye movement which they perform quickly and effortlessly when looking at any distant object in the normal way.

The following explanation is offered. Although the image of each card is at infinity in the mid-line, the patient thinks that he is looking at a card a few inches from him. He has a very vivid sense of the position of the cards built up from a variety of clues; one being that he is all but holding the cards in his hand, and another that the cards obstruct his view of objects behind them. This estimate of the cards as being near has a strong influence on convergence. When the two cards are moved apart the incipient occurrence of double vision acts as a strong stimulus to reduce the angle of convergence, while the psychological estimate of the card position remains a strong stimulus to maintain it. These two opposing mechanisms produce a sense of strain, though we cannot say exactly how, as we do not know what is the condition of the extra-ocular muscles during this struggle. In view of this ignorance, we must approach this and other eye exercises on the instrument with due care and be ready to learn from the results obtained.

It would appear to be most important to assess correctly the part played by the accommodative effort and by the mental estimate of distance in determining the degree of convergence. Such an assessment has a direct and important bearing on the nature of squint and latent squint and on their treatment; we are at present carrying out an investigation of this subject.

EXERCISE 4. VARYING RELATION BETWEEN ACCOMMODATION AND CONVERGENCE.

The instrument is set as in Exercise 3, except that the near ends are now slightly separated. The cards are made to approach the eyes along the rails, and the accommodation will now be accompanied by less than the normal amount of convergence. The near ends may be further separated and the movement repeated. The wider the separation of the near ends the less is the convergence, until finally

when the near ends are opposite the eyes the convergence is zero for all positions of the cards, and the exercise has become Exercise 2.

Further variety can be introduced by varying the position of the far ends of the rails. The separation of the far ends determines the convergence when the accommodation is relaxed, while the separation of the near ends determines the convergence while an accommodative effort is being made. Accommodation and convergence may thus be exercised in almost any desired relationship.

With the cards at the far ends of the rails, the degree of convergence cannot exceed an amount corresponding to an angle of 16° between the two visual axes. This is less than that obtainable on a synoptophore and will be inadequate in some cases. It may be increased very simply by adding base-out prisms in front of the existing half lenses. This increases the angle of convergence for all positions of the rails but does not extend the range over which convergence may be exercised.

Cards for the Stereoscope

The limit to the size of the cards for use in this stereoscope is set by the exercise involving accommodation and convergence in their normal relationship (Exercise 3, p. 236; Fig. 4, p. 227). Fig. 14 shows how this exercise determines the maximum size of the cards. It is clear that if the cards are too large their centres

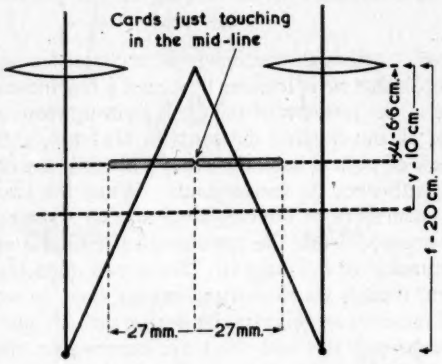

Fig. 14.—Condition limiting size of cards. They are moving towards the mid-point between the two lenses and are 6.6 cm. from the lens; accommodation is 10 dioptres.

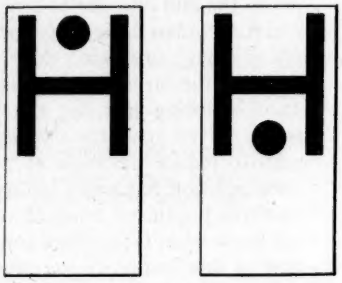

Fig. 15.—Suitable cards. Actual size, 2″ high × 1″ wide.

cannot approach each other sufficiently closely. The limiting size is arrived at as follows:

First a line is drawn from each focal point to the point midway between the two lenses. It will be remembered that this is the locus along which the card centres will move in this exercise. Next the maximum accommodation required in the exercise must be decided. We will fix this arbitrarily at 10 dioptres, which means that the virtual image of the cards must approach to within 10 cm. of the plane of the lenses. The focal length of the lens in the present stereoscope is 20 cm., this value having been chosen to make the instrument of reasonable proportions. Substituting the values $f = +20$ cm., $v = -10$ cm. in the formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, we get $u = -6\frac{2}{3}$ cm. The nearest position of the cards is therefore $6\frac{2}{3}$ cm. from the plane of the lenses. The distance apart of the

lens centres is 80 mm., hence this is also the distance apart of their two foci. The distance apart of the two card centres is now given by simple proportion and is equal to $80 \times \frac{6\frac{3}{4}}{20} = 27$ mm. or approximately 1″. Thus for this particular stereoscope the cards must not be more than 1″ across. They may conveniently be made 2″ high. Although this is smaller than is usual there is no trouble at all in seeing the pattern on the cards, and they are in fact quite large enough.

The Pictures on the Cards

For stereoscopic pairs any of the usual drawings will serve. For cases where binocular vision is not well developed and suppression is liable to occur, the pair of cards shown in Fig. 15 may be used. The whole of the two letters is identical so there is plenty of stimulus to fusion. According to whether the patient sees a dot at the top of the picture, or at the bottom, or whether he sees two dots, the operator can tell whether he is using the left eye, the right eye, or both eyes. These cards have been drawn in accordance with the principles already described.

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Brit. J. Ophthal. (1952) 36, 240.

DACRYOCYSTORHINOSTOMY BY INTUBATION*

BY

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THE value of draining an infected sac into the nose was recognized 1500 years ago by surgeons of the Byzantine School, who performed a crude dacryocystorhinostomy by passing a cautery through the sac and lacrimal bone. But such openings made by simple penetration rapidly close, and much surgical ingenuity has since been devoted to the problem of fashioning a permanent communication. At the beginning of the 20th century, Toti (1904) laid the foundation of the modern operations of external dacryocystorhinostomy. Since then the careful work of many surgeons has resulted in procedures which give a high percentage of success—Traquair (1940), 80 per cent.; Scott (1949), dacryocystitis 99.4 per cent., epiphora 76.9 per cent.; Stallard (1950), 89 per cent.; Rycroft (1951), over 80 per cent. Despite these excellent results, dacryocystectomy is still being very generally performed because it is believed that dacryocystorhinostomy is successful only in exceptionally experienced hands, is time-consuming, is often beset with technical difficulties, and sometimes involves painful post-operative treatment.

RATIONALE OF INTUBATION

Complicated techniques of dacryocystorhinostomy have been elaborated to circumvent nature's efforts to close the artificial opening, but this result can be more simply and effectively achieved by inserting a small polythene tube which passes from the sac through the lacrimal bone into the middle meatus. With such a tube in position, permanent drainage from the sac to the nose is assured, and, as the *x* ray shows, lipiodol passes into the nose within a few minutes of its injection into the sac (see Figure, opposite).

The use of this tube materially simplifies dacryocystorhinostomy. An opening of only 6 mm. in diameter is required in the fragile lacrimal bone, and the suturing of the mucosa is made unnecessary as the tube holds this in place during healing.

No objections have been found to the permanent retention of such a tube, polythene is in general use for many purposes and has been found to be innocuous. The author has used indwelling tubes for the repair of different parts of the lacrimal drainage system since 1944 with no evidence of any tissue intolerance and an interim report on various uses was presented in 1947 (Summerskill, 1948). In that communication two methods of dealing with dacryocystitis due to an obstructed naso-lacrimal duct were described:

(*a*) insertion of a tube into the naso-lacrimal duct,
(*b*) by-passing the duct by the method under review.

* Received for publication December 22, 1951.

FIGURE.—Right sac intubated about 1 year before *x* ray, and left sac a few weeks before. Cannulae have been introduced to indicate openings of tubes.

An extensive trial of intubation of the duct produced only about 60 per cent. of successes, because fibrosed ducts, even after probing, will not accept a tube of adequate calibre and moreover progressive cicatrization often forces the tube gradually upwards into the sac. Better results by the second method were later reported (Summerskill, 1949) in a series of 28 cases; it was then suggested that

> further observation on more cases will be required to confirm that these results are permanent, but . . . this little operation will I believe provide the answer to the problems of severe idiopathic dacryocystitis.

Later experience has confirmed this opinion. Judged by the disappearance of symptoms and the unobstructed passage of fluid into the nose from a syringe inserted into the sac, this operation has been successful in 96 per cent. of suitable cases. The failures are due to the difficulties occasionally encountered in satisfactorily closing the excessively shrunken type of fibrosed sac. In view of the simplicity and reliability of this procedure, it should rarely be necessary to deprive patients with dacryocystitis of the comfort of a functioning lacrimal drainage system by dacryocystectomy.

SELECTION OF CASES

This operation is indicated for dacryocystitis due to any form of simple obstruction of the naso-lacrimal duct which cannot be resolved by more conservative measures.

Idiopathic dacryocystitis is the commonest form (76 per cent.). It shows a definite hereditary tendency and a higher incidence among women, and is appar-

ently caused by developmental faults in the bony canal (Summerskill, 1948). With this class of case conservative measures generally fail, and it is eminently suitable for treatment by dacryocystorhinostomy.

Infantile dacryocystitis (about 22 per cent.) follows congenital obstructions of the membranous duct and can usually be cured by conservative methods, if not too long delayed. Some infantile cases (2 per cent.) are early examples of the idiopathic disease. These will relapse after conservative treatment and later require dacryocystorhinostomy.

In the third group, representing some 2 per cent. of the total, the obstruction is due to acquired disease—to new growths in the sac, antrum, nose, or surrounding tissues, to specific infections, or to trauma. If the sac is not too badly damaged, some of the traumatic cases are suitable for dacryocystorhinostomy. The symptomatic epiphora of the other forms is of little importance compared to the gravity of the primary disease, and care must be taken not to confuse them with the simple idiopathic dacryocystitis.

As this operation imposes no more strain on the patient than a dacryocystectomy, it is, subject to reasonable health, suitable for patients of all ages after early childhood. The author's series contains cases ranging from 4 to 72 years of age.

Operation is not undertaken until conservative treatment has failed. This consists of a series of irrigations of the sac under pressure, the cannula of the lacrimal syringe being passed into the duct, if necessary, to secure a patent passage to the nose. It may be supplemented by appropriate systemic treatment depending on the organisms found to be present. Probes should not be used; they do not cure the obstruction and they subject the patient to unnecessary pain.

The operation is carried out in the presence of a fistula or of a sub-acute exacerbation of the infection, but it is generally convenient to postpone it in the presence of an acute dacryocystitis until the oedema has subsided under treatment.

Any lacrimal obstruction above the sac—in the lid, the lower canaliculus, or the sinus of Maier—, or nasal conditions which would prevent the introduction of the polythene tube—such as a gross deflected septum or a polyp—,need to be rectified before operation.

Operation

Instruments.—The special requirements for this operation are the polythene tubes, an introducer, and three probes of suitable size*. The tubes are 5 mm. in diameter and 10 mm. in length, bevelled at one end and with triangular flanges at the other to hold them in the sac. The introducer is a rod, 4 mm. in diameter with a shoulder 12 mm. from the end. Three double-ended bulbous probes, the largest 6 mm. in diameter, are used to perforate the lacrimal bone and to enlarge the stoma sufficiently for a tube to fit.

Anaesthesia.—Premedication consists of omnopon g. 1/3 and scopalamine g. 1/150 (for an average adult) unless it is necessary for the patient to go home on the same day, when nembutal g. 3 and atropine g. 1/100 are used. Anaesthesia is induced by thiopentone and followed by nitrous oxide, oxygen, and minimal ether. In robust patients a relaxant is used, then a non-cuffed orotracheal tube, as large as possible, is passed. The pharynx is packed with gauze squeezed out in normal

* Instruments to these designs are supplied as a set with a lacrimal syringe, a Meyer's straight silver cannula, and a perforated metal box for containing the tube during sterilization, by Messrs. Down Bros., Meyer, and Phelps Ltd., 92, Borough High Street, London, S.E.1.

saline, and anaesthesia is continued on an open circuit. At the end of the operation, after removal of the packing, the pharynx is inspected with a laryngoscope and blood clot if present cleared out with the sucker (Dr. P. Merlin).

Technique.—The incision runs from the medial palpebral ligament 3 mm. internal to the medial canthus and curves downwards and slightly outwards along the anterior lacrimal crest to the level of the upper opening of the bony canal. The skin edges are undermined and the orbicularis split; the ligament is exposed but left intact. A speculum is inserted and the lacrimal fascia is exposed by blunt dissection. An incision of 8 mm. is made through the fascia into the sac in its long axis terminating below just above the commencement of the duct, and a catgut suture is inserted into each edge of the wound to act as traction sutures. When there has previously been some peridacryocystitis, it is often convenient to insert the suture before making the incision and to pass a probe through the canaliculus to act as a guide to the sac cavity. Gentle traction on the sutures is maintained, and the smallest of the three probes is passed into the sac and down into the commencement of the naso-lacrimal duct. This is done because the duct is used as a guide to the lowest part of the lacrimal bone. The anterior part of the lacrimal fossa is formed by the hard frontal process of the maxilla, the lacrimal bone lying behind it with its descending process forming the posterior part of the bony canal. Therefore, to perforate the lacrimal bone at its lowest part, the probe is withdrawn slowly from the duct, and as its point leaves the upper end it is passed medially and slightly backwards and downwards. Little pressure is required to perforate the bone, and the probe is passed on until it touches the nasal septum. The opening is enlarged by passing the medium-sized and then the largest (6 mm.) probe. The field is kept clear of blood by a sucker and oozing is reduced considerably if each probe is left in position for a minute before withdrawal. The polythene tube is then inserted on the applicator and care is taken to see that it is firmly in position with the flanges in the long axis of the sac. Penicillin-sulphathiazol powder is insufflated into the sac cavity and wound. The tube is washed through with the lacrimal syringe to free it from blood and debris, and the sac is closed by tying the traction sutures. The skin is closed by three or four interrupted silk sutures and a dry dressing held by strapping is applied.

Post-Operative Supervision.—Little post-operative treatment is required, for efficient drainage is assured by the tube. Young patients may leave hospital directly they have fully recovered from the anaesthetic; elderly patients are kept in over-night. Healing usually occurs by first intention and the skin sutures are removed after 7 days. The dacryocystitis rapidly subsides, systemic penicillin or other suitable antibiotic for a few days is indicated if operation has been undertaken in the presence of a sub-acute attack. A fortnight after operation the sac is gently irrigated with sol. sulphacetamide 30 per cent. to demonstrate that drainage is satisfactory and to wash through any debris and blood clot. Earlier irrigation should be avoided but may be required if the tube is not left clear at the time of operation. Normally the fluid passes easily into the nose and no further treatment is required.

It is occasionally difficult to secure an efficient apposition of the sac wall when it has been damaged by repeated attacks of peridacryocystitis, and the tube may later protrude. The tube in such cases is easily removed through an incision over it and

if the stoma is established it will often continue to function leaving satisfactory drainage. Otherwise no late complications have been encountered.

SUMMARY

Dacryocystorhinostomy, not dacryocystectomy, is the treatment of choice for dacryocystitis due to simple naso-lacrimal duct obstructions resistant to more conservative procedures. The operation has not been generally adopted because it is believed that special experience is required to fashion an opening between the sac and the nose which will not later close. The use of a polythene tube, which is passed from the sac through the lacrimal bone to the middle meatus, gives reasonable assurance of permanent drainage and materially simplifies dacryocystorhinostomy technique. The operation is described.

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Brit J. Ophthal. (1952) 36, 245.

PATHOLOGICAL STUDY OF RETINOBLASTOMA TREATED BY RADON SEEDS AND RADIUM DISKS*†

BY

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London

RADIATION is a type of energy which occurs in two forms:

(1) Electro-magnetic vibration. Light. Roentgen rays.
(2) Corpuscular radiation. α and β rays. Neutrons.

That part of the Arndt-Schulze law which states that small doses of radiation stimulate cell proliferation is strongly disputed in the literature of radio-biology; in fact Strangeways and Hopwood (1926) found no evidence of any stimulating effect by *x* rays on cells in tissue culture and this has also been confirmed by such an authority as Bloom (1948). The medium irradiation doses are depressive and the large doses are destructive. The effect of irradiation is governed by the specific radio-sensitivity of cells and tissues, and the factors concerned in this are the equation of several variables. The more important of these are the following:

(1) *Degree of Cell Differentiation.*—The more undifferentiated, immature, atypical, character of the tissues, and the ability of certain cell strains to proliferate rapidly the greater is the radio-sensitivity.

(2) *State of Mitotic Activity of the Cells.*—During mitosis there is increased sensitivity of both normal and pathological cells which rises in the prophase and is greatest in the equatorial-plate phase. Strangeways and Hopwood, when investigating the effect of *x* rays on mitosis in tissue cultures, found that cells pass through a phase immediately before visible prophase during which the physiological processes of the cell are especially liable to be disturbed. The process of cell division becomes abnormal and may result in complete disruption of the cell. Indeed, during the chromosome state a larger surface of chromatin is exposed to irradiation than at other times in the life of the cell. There are waves of mitosis in normal tissues which must be taken into account.

When cell metabolism is increased in direct relation to cell growth and where the degree of swelling of the colloid is augmented radio-sensitivity is higher.

(3) *Nature of the Tissues in which the Neoplasm arises.*—In general, if the tissue from which the growth arises is radio-sensitive, then the neoplasm will also be radio-sensitive, and Ellinger (1941) has stated that " tumours arising in radio-resistant tissue are invariably radio-refractory and are to be described as radio-resistant tumours". The latter is not true in the case of retinoblastoma, for although the retina in common with other parts of the nervous system is resistant

* Received for publication November 28, 1951.
† First part of the William McKenzie Memorial Lecture, 1951.

to irradiation, even at doses which are several times more than that which injures blood-forming tissues, the undifferentiated atypical cells of retinoblastoma are highly radio-sensitive. So with retinoblastoma there is the unique and favourable condition of a very radio-sensitive neoplasm arising from relatively radio-resistant tissue.

(4) *Blood Supply of the Neoplasm.*—The richer the blood supply the more radio-sensitive is the neoplasm. The reason that smaller neoplasms are more radio-sensitive than larger growths is probably due to the fact that they have a better blood supply. This is certainly true in retinoblastoma. It is evident that radio-sensitivity is reduced in anoxaemia.

(5) *Age.*—Radio-sensitivity is greater in the young than in the old.

(6) *Constitutional State.*—Radio-sensitivity is reduced by cachexia, suppuration, tuberculosis, and syphilis.

(7) *Previous Irradiation Treatment.*—This may cause the tissues to acquire resistance to radium and *x* rays.

Material of Present Investigation

I have studied pathologically eight eyes containing irradiated retinoblastoma. Two were completely full of the growth and were used in 1930 and 1931 to assess the effective range of a 3.5 mc. radon seed inserted interstitially and left in place for 10 days. One child had a clinical cure of retinoblastoma in the remaining eye, but unfortunately died 11 months later from a recurrence in the orbit from which the other more severely affected eye had been excised. Another child, one year after successful irradiation of three large masses of retinoblastoma around the optic disk, had an intra-ocular haemorrhage and complicated glaucoma. Three children had more than half the retina affected by the growth and a total detachment, and so were most unfavourable cases for irradiation; and there was one patient in whom three-quarters of the retina were involved and who ultimately lost the eye from intra-ocular haemorrhage and complicated cataract. Serial sections were cut, 16μ thick, and stained with Mallory's phosphotungstic acid haematoxylin, Feulgen's solution, Heidenhain's iron haematoxylin, haematoxylin and eosin, van Gieson's stain, and Hotchkiss's modification of McManus's stain.

Histo-Pathological Changes

Even though the cell nucleus is no longer regarded as the only radio-sensitive component of the cell (the cytoplasm being relatively radio-insensitive), it is still consistent with modern concepts to regard it as an important indicator of post-irradiation intra-cellular changes and as an expression of radio-sensitivity. Nevertheless, it is probable that the nuclear changes are not entirely the result of direct irradiation but may be due also to cytoplasmic changes.

The histological features of an irradiated cell are increases in the size of the nucleus and of the cytoplasm. In the nucleus the chromatin is clumped, broken up into minute spherules, and distributed irregularly around the periphery on the nuclear membrane (pyknosis). In some cases the chromatin granules project from the periphery of the cell as small excrescences. Lobulation is sometimes evident, the nucleoli assume a signet-ring shape, liquefaction occurs with vacuole formation, and disintegration of the nucleus (karyorrhexis) is followed by its fragments entering the cytoplasm. The cell outline becomes less distinct, vacuolation occurs and the size of the cytoplasm increases. Fig. 1 shows these changes in retinoblastoma cells 10 days after interstitial irradiation with a 3.5 mc. radon seed.

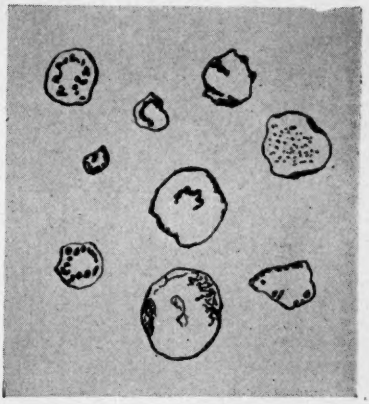

FIG. 1.—Retinoblastoma cells 10 days after being within the effective zone of gamma emanations from a 3.5 millicurie radon seed inserted interstitially into the neoplasm. Pyknosis, chromatin excrescences from the cell membrane, lobulation, and karyorrhexis are shown. (From *Brit. J. Ophthal.*, Monograph Suppl. No. 6, Gifford Edmonds Prize Essay, 1932.)

Mitosis.—Atypical mitosis is shown by clumping and lagging of the chromosomes, and by multipolar asters. Mitosis does not become complete and may remain at the equatorial-plate stage. In the case of those cells which had already begun to divide when irradiation struck them, the process was completed but the daughter cells developed into giant cells. Ultimately denaturation of the proteins and their precipitation produces an irreversible change characteristic of irradiation coagulation necrosis in the cell which is radio-sensitive. In the case of retinoblastoma it is most likely that this change accounts for the altered ophthalmoscopic appearance of the neoplasm 2 or 3 days after irradiation, for its greyish-white, granular appearance changes to a dense white flocculent mass, from which flakes like curdled milk separate off.

Glücksman and Tansley (1936) found in the immature eyes of newborn rats that quite small exposures of radium cause a complete disappearance of cell division for about 6 hours, mitosis then reappears, but many of the dividing cells are markedly abnormal and the recovery is accompanied by a widespread cell degeneration in the outer part of the retina which is still undifferentiated at the time of exposure. The amount of degeneration after irradiation is proportional to the amount of cell division in the exposed tissue.

Vascular Changes.—It is evident from both ophthalmoscopic and microscopic examinations that the ultimate fate of irradiated blood vessels is attenuation with the disappearance of part or all of the vascular tunics.

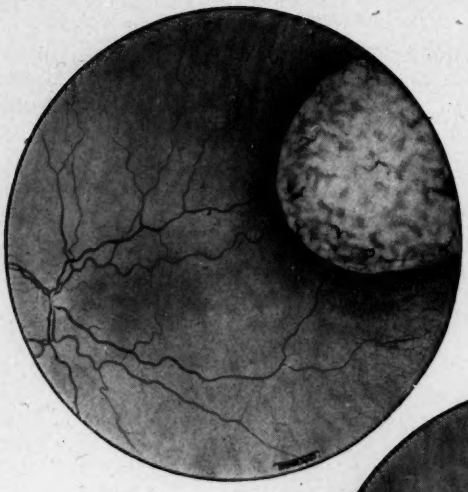

FIG. 2(*a*).—Retinoblastoma in right eye before irradiation.

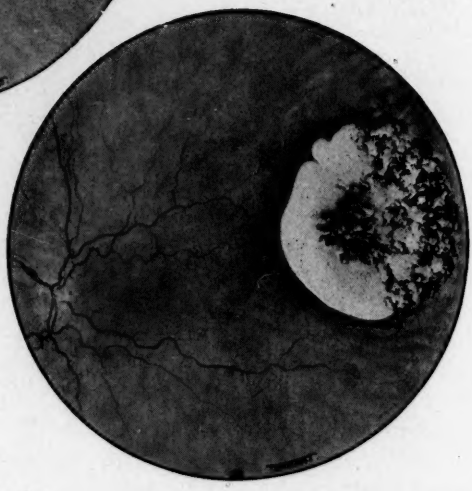

FIG. 2(*b*).—Vascular changes at and around site of retinoblastoma after successful irradiation by radon seed sutured to sclera.

Figs 2(*a*) and 2(*b*) illustrate these changes on the nasal side where a retinoblastoma was successfully treated by suturing a radon seed to the sclera.

Microscopic examination reveals a deep brilliant pink staining of the collagen of the tunica adventitia which, in cases examined one month after radium or *x*-ray treatment, is a purple pink. Individual collagen fibres become fewer and thicker and some merge together. Most of the collagen fibres separate and project into the surrounding tissues at angles; they are wavy and some become detached. One week after irradiation these fibres become granular and disappear. In sections examined 4 to 5 months after irradiation there is no adventitia.

In the tunica media the muscle fibres become swollen and the nuclei enlarge; degeneration occurs late in some cells after high irradiation doses and they ultimately disappear. Nevertheless, muscle and elastic membrane are considered to be radio-resistant.

The endothelial cells of the tunica intima become swollen and may obliterate the lumen of the vessels only after very high irradiation doses.

One to 2 weeks after irradiation there is a decrease in the total number of blood vessels; some are distended with blood, and others are collapsed and invisible. Indeed, in some only the naked elastic membrane remains without endothelium to line the lumen.

The varicose appearance and irregularities in calibre of some smaller vessels may be due to compression by changes in the surrounding connective tissue as well as to the irradiation changes in the vessel wall.

The admirable work of Ballantyne (1941) on the vascular changes which follow irradiation of an eye with haemangiogliomatosis retinae showed degeneration and swelling of the collagenous elements of the outer coats of the blood vessels with an abundant proliferation of elastic fibres. In the pathologically distended vessels, the tunica intima was greatly thickened and became hyaline. Such vessels showed thickening of their walls, feeble staining with eosin, and a reduced number of nuclei. In a few instances the layer of subendothelial tissue was thin. Pathologically distended vessels were more radio-sensitive than normal vessels. In the capillaries, irradiation is said to paralyse the cells of Rouget, to increase their sensitivity to dilator stimuli, and to lessen it for constrictor impulses.

These vascular changes play an important part in the disappearance of the neoplasm. Incidentally, they are also responsible for such late complications as intra-ocular haemorrhage, irradiation cataract, and the slow healing of incisions in the conjunctiva and extra-ocular muscles when the radium has been placed unavoidably near these structures.

Nerve Tissue Changes.—Desjardins (1931) found that the nervous parts of the eye are not readily damaged by *x* rays, and Lyman, Kupalov, and Scholz (1933, quoted by Bloom, 1948), after reviewing the German and Russian literature on experimental irradiation of adult animals' eyes, stated that little or no direct change was seen in the nerve cells or fibres of the retina.

Changes in the Neoplasm.—Fig. 3 shows part of the retina which before

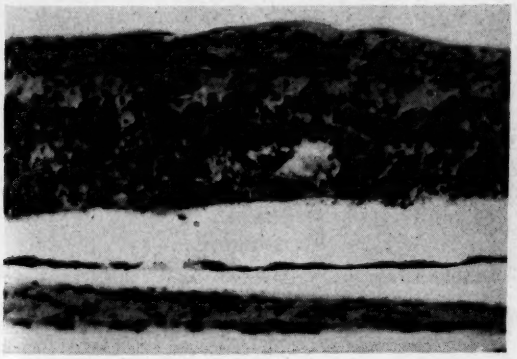

FIG. 3.—Photomicrograph of irradiated retina and choroid at site of retinoblastoma. There are no retinoblastoma cells. The vascularity of the atrophic retina and choroid is much reduced. The layer of rods and cones has disappeared and the other layers of the retina are disorganized. Pigment deposits are present in the outer nuclear and molecular layers.

irradiation was involved in the neoplasm. In this degenerate, disorganized, atrophic area there are no retinoblastoma cells, the neoplasm has completely disappeared. The reduced vascularity of both retina and choroid is obvious.

In some cases traces of neoplastic cells persist in compressed columns and clumps surrounded by fibrous tissue, and in others there are pale-centred islands of degenerate, necrotic, and distorted cells, which stain a mauvish-pink colour with haematoxylin and eosin (Fig. 4). The central vessel in every island is absent, the cell and nuclear membranes are very faint, and chromatin

FIG. 4.—Photomicrograph of irradiated islands of retinoblastoma cells which stain a mauvish-pink with haematoxylin and eosin. The central vessel of each island is absent, the cell and nuclear membranes are very faint, and chromatin fragments stain darkly. Fibrosis is evident around some of the islands.

fragments stain darkly with the basic dyes. Around such islands appear attempts at fibrosis. In one instance there were islands of retinoblastoma cells with the nucleus staining well and histologically not necrotic which remained apparently inactive until the child died from recurrences which arose in the orbit of the excised eye nearly a year later. A similar case in which clumps of retinoblastoma cells remained thus for 8 years without proliferation has also been reported.

FIG. 5.—Photomicrograph of clumps of swollen 'ghost' cells in nerve fibre layer.

Calcification occurs in some islands after degenerative changes. Fibrosis around groups of retinoblastoma cells may be the sequel to cellular degeneration and is not specific to irradiation.

The swollen 'ghost' cells occur in the nerve fibre layer (Fig. 5), on the internal

FIG. 6.—Photomicrograph of swollen 'ghost' cells on internal limiting membrane.

limiting membrane (*Fig. 6*), and in the space between the rods and cones and retinal pigment epithelium.

At and around the site of irradiation there occurs oedema of the retina (Fig. 7) which may extend 4 or 5 mm. beyond the periphery of the neoplasm, and in specimens examined up to a year after radium treatment cystic spaces appear in the outer nuclear layer (*Fig. 8*). The periphery of the zone of

FIG. 7.—Photomicrograph showing oedema of retina at and around irradiated site.

FIG. 8.—Photomicrograph showing cystic spaces in outer nuclear layer one year after irradiation.

intense irradiation, where the radon seed or disk has been applied, shows a crenated fringe of coarse broken pigment (Fig. 2*b*) which in sections is represented by spherical clumps of retinal pigment epithelial cells, and the fine pigment dusting of the retina peripheral to the characteristic irradiation scar is shown by little irregular-shaped deposits of dark and honey-coloured pigment in the outer and inner molecular layers and in the ganglion cell layer of the atrophic retina (Fig. 9).

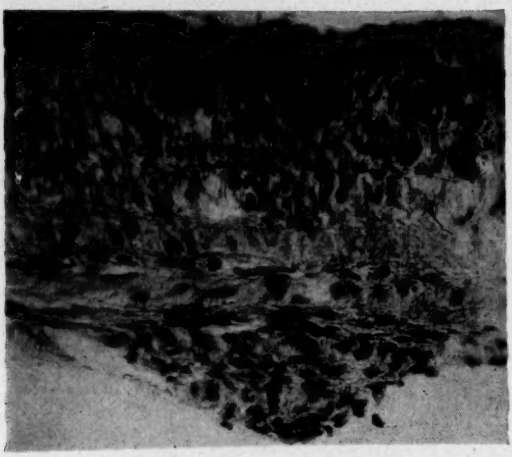

FIG. 9.— Photomicrograph showing irregular-shaped deposits of pigment in outer and inner molecular layers and in ganglion cell layer. There is also a fibrous nodule in the nerve fibre layer.

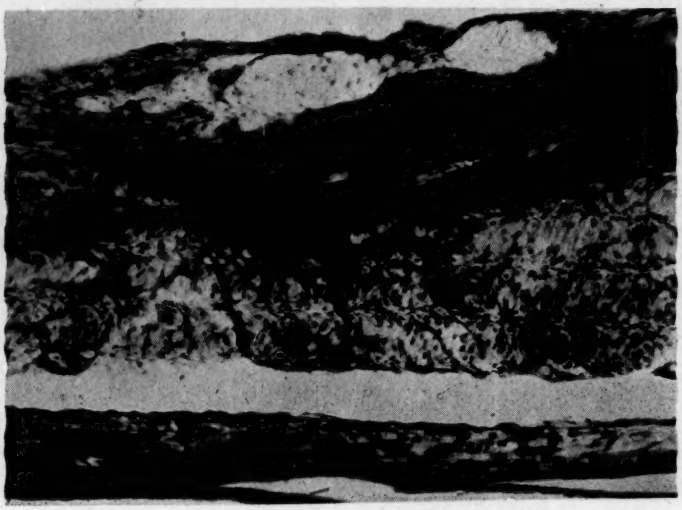

FIG. 10.—Photomicrograph showing fibrosis in degenerative nerve fibre and ganglion cell layers.

Many of the blood vessels disappear, and the larger vessels become attenuated, a feature evident on ophthalmoscopic examination. Some of the vessels are thickened, the nuclei in the structures which form the vascular tunics stain faintly, and hyaline changes are present.

The ganglion cell layer is degenerate and much of it is replaced by spindle cells, presumably young fibrous tissue, which at some sites projects forwards as a small nodule (Figs 9 and 10).

In the outer nuclear and molecular layers there are in some specimens irregular-shaped deposits of homogeneous exudate and hyaline material, which stain pink with eosin. The supporting fibres of Müller are distorted at the edge of the neoplasm.

The rods and cones are destroyed and granular pigmented debris is present between the external limiting membrane and Bruch's membrane. Retinal haemorrhages occur particularly in the ganglion cell and inner molecular layers (Fig. 11).

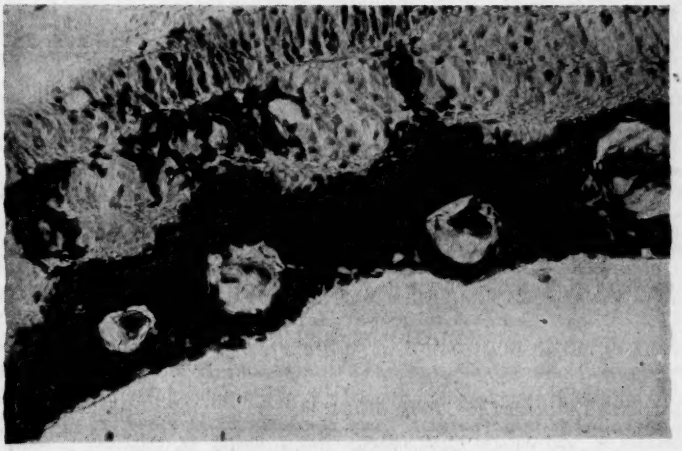

FIG. 11.—Photomicrograph showing retinal haemorrhages in ganglion cell and inner molecular layers.

The choroid at and around the site of irradiation becomes thin and atrophic, its vascularity is much reduced, and the chorio-capillaris becomes obliterated. *Infiltration of the choroid by retinoblastoma cells is regarded by radio-therapists as a bad prognostic sign.* Fig. 12 *(overleaf) shows irradiation cataract with so-called 'bladder cells' at the equator and in the posterior part of the cortex.* In one case the epithelium of the lens capsule completely surrounded it.

It is possible that the destruction of a large mass of retinoblastoma occupying more than half the eye may have produced a toxin which has ultimately caused an endophthalmitis in one case treated by radon seeds, and in two treated by deep *x* rays. Iridocyclitis and complicated glaucoma

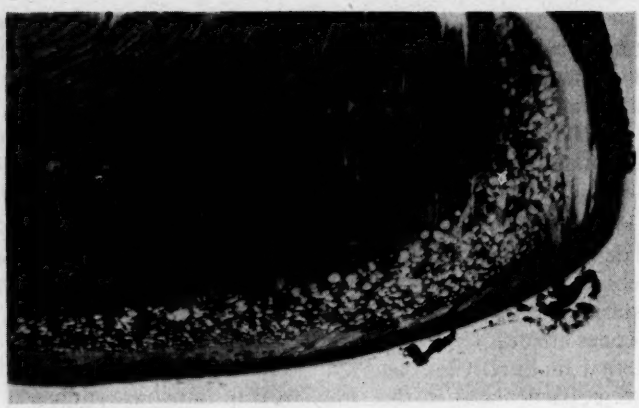

FIG. 12.—Photomicrograph of irradiation cataract showing 'bladder-cells' at equator and in posterior part of cortex.

are sequels which are rarer after treatment by radon seeds and radium disks than after deep *x* rays.

I acknowledge with gratitude the work done by the Pathological Department (Dr. Norman Ashton) and the Medical Illustration Department (Dr. Peter Hansell) of the Institute of Ophthalmology in preparing the serial sections and in taking the photographs.

I thank the William McKenzie Memorial Committee for their kind permission to publish this part of the lecture.

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Brit. J. Ophthal. (1952) **36**, 255.

IMPROVED ILLUMINATION IN INDIRECT OPHTHALMOSCOPY*

BY

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THE indirect method of ophthalmoscopy offers several advantages over the direct method; these include larger field of view, better penetration of hazy media, greater depth of focus, and closer approach to the ora serrata (Schepens and Bahn, 1950). These features are of especial importance in cases of detachment of the retina, where the necessity of studying the topography and locating all the tears was pointed out by Gonin (1934), and has since been stressed by several authors, including Weve (1934), Arruga (1946a), Schepens (1951), and McDonald (1951).

Unfortunately, many ophthalmologists consider the indirect method difficult and unsatisfactory, objecting that the illumination is feeble and/or that the field is not much larger than obtained by the direct method. The problem may be studied qualitatively by means of simple ray diagrams.

Fig. 1 shows a typical arrangement using the Morton or Loring reflecting ophthalmoscope. For the purposes of the comparisons to be made, it will be assumed that the source of light is a frosted bulb in a chimney, that the concave mirror has a focal length of 25.0 cm. and a diameter of 2.8 cm., and that the lens is at about its own focal length from the patient's pupil. Rays of the observing system are omitted. It will be seen that the mirror intercepts a narrow cone of light from the source and reflects it through the central portion of the lens into the patient's eye. The field of illumination is determined by the angle of the cone of rays in the vitreous, which is limited in this case by the diameter of the mirror. The field of observation, however, is not limited by the mirror, and is ordinarily larger than the field of illumination (Duke-Elder, 1938).

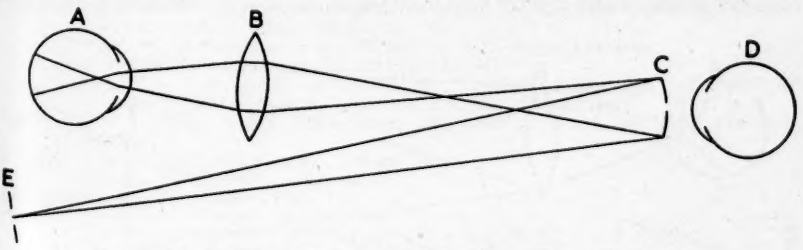

FIG. 1.—Typical path of illuminating rays, using small concave mirror.
A, patient's eye ; B, lens ; C, mirror ; D, observer's eye ; E, source of illumination.

* Received for publication December 19, 1951.

The usual method of enlarging the field of illumination is to replace the concave mirror with a plane one, as shown in Fig. 2. Here the mirror receives a narrow cone of light and reflects it through the full aperture of the lens into the eye. While the cone of rays in the vitreous has been widened, the amount of light received from the source is no greater than before, and thus the unit brightness on the retina is diminished. Although, with either the concave or the plane mirror, some improvement may be made by using a light source of greater brilliance and larger area, the scattered light has a tendency to degrade the contrast of the ophthalmoscopic image and to impair the observer's dark adaptation.

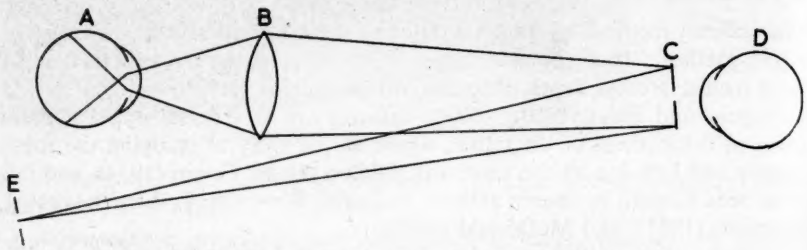

FIG. 2.—Typical path of illuminating rays, using plane mirror.

There remain other, more efficient methods. One ingenious solution has been described by Arruga (1946b); here focal illumination is directed on to the mirror from a small lantern-slide projector, in which the focusing adjustment provides control over the convergence or divergence of the light, and the slide carrier provides a convenient means of restricting the light by diaphragms or filters. Certain types of microscope illuminators should serve as well. Epstein (1950) has adapted an otolaryngologist's head-lamp for use in ophthalmoscopy during surgery. Of the self-luminous hand ophthalmoscopes, only the larger models with 6- or 12-volt bulbs furnish sufficient light for satisfactory indirect ophthalmoscopy. For routine clinical and surgical use, however, an arrangement simpler than any of the foregoing may be preferred.

Increasing Brightness and Field

One answer to the problem is shown in Fig. 3. Here a concave mirror of large diameter gathers a wide cone of light from the source, and on reflection gives it such

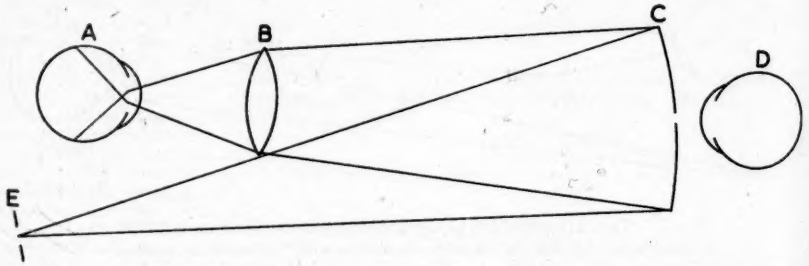

FIG. 3.—Path of illuminating rays, using proposed large concave mirror of long focal length.

convergence that it just fills the aperture of the lens. As in the original stand-type instrument of Ruete (1852), the maximum field of illumination is assured not only by the use of the full lens aperture, but also by the light being brought to a focus closer to the focal point of the lens than would be the case if a short focal length concave mirror were used. The intensity of the illumination is proportional to the area of the mirror. An experimental mirror has been made with a focal length of 53.0 cm. and a diameter of 8.0 cm. Through a dilated pupil in an emmetropic eye it evenly illuminates a field of up to about eight disk-diameters, depending on the lens used. In detached areas the field is less because of the quasi hyperopia. The brightness is approximately seven times that from a plane mirror.

The advantages of such a wide field and such brightness in the study of detachments in the surgery, at the bedside, and in " ophthalmoscopic control " in the operating theatre are evident.

Two important features of an ophthalmoscope for use during surgical operations are that it be " boilable ", and that it be arranged for use with a headband, so that the surgeon may have a free hand. It is proposed, therefore, that a mirror of 51.0 cm. focal length, 8.9 cm. diameter* and 0.4 cm. central opening be mounted on an aluminium backing having a ball fitting, similar to that of an otolaryngologist's head mirror. No (Recoss) lens disk is necessary if the surgeon has normal accommodation or wears appropriate spectacles. If the headband mounting is not desired, a handle may be screwed into a threaded hole in the ball fitting, and the mirror used as in the " simple " ophthalmoscope of Liebreich or of Follin.

While the effect of the focal length of the lens on the ophthalmoscopic image is well known, the influence of the form of the lens is often neglected. The symmetrical biconvex form of lens is usually supplied for this purpose, although the peripheral blurring and field-limiting effect of spherical aberration may be slightly reduced by use of the plano-convex form (Polack, 1939). Still better results may be obtained by use of an aplanatic lens of the type formerly made by Zeiss for the Gullstrand series of ophthalmoscopes. The coating of the lens with magnesium fluoride to abate reflections is a worthwhile improvement.

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* Computed for use with an aplanatic lens of 7.0 cm. focal length and 5.0 cm. diameter.

Brit. J. Ophthal. (1952) 36, 258.

INFLUENCE OF THE SYMPATHETIC NERVOUS SYSTEM ON THE INTRA-OCULAR PRESSURE AND VASCULAR CIRCULATION OF THE EYE*†

BY

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From the Institute of Ophthalmology, London
Director of Research: Sir Stewart Duke-Elder

THE first section of the following paper describes the effects on the intra-ocular pressure of cutting and stimulating the cervical sympathetic nerves in cats and rabbits. This section is a repetition of previous workers' experiments, except that we have recorded simultaneously on the same film the intra-ocular pressure of both eyes and the blood pressure, thus enabling intra-ocular pressure changes resulting from general blood pressure effects to be distinguished from local sympathetic effects.

The subsequent sections deal with the appearance *in vivo* of the aqueous veins and choroidal circulation in rabbits. The changes observed during stimulation of the sympathetic nerve and the results of injecting dyes and Indian ink into the carotid artery and anterior chamber are described.

Historical Survey

It is now almost 50 years since Henderson and Starling published their classical paper on the effect on the intra-ocular pressure of stimulation of the sympathetic and third cranial nerves of cats. Höltzke (1883) and Adamük (1866) seem to have been the first workers to investigate adequately these effects and to describe the changes in the intra-ocular pressure on section of the cervical sympathetic. Since then many experiments have been performed by different workers.

A fall in the intra-ocular pressure on cutting the cervical sympathetic nerve was recorded by Höltzke (1883), Graser (1883), Adamük (1866), Lagrange and Pachon (1900), Schmidt-Rimpler (1900), and Stock (1910).

Leber (1903) noted a slight rise followed by a slower fall in the intra-ocular pressure after stimulating the sympathetic in dogs and cats. In rabbits the initial rise was absent. Similar results are reported by Henderson and Starling (1904), Lodato (1906), Wessely (1908), Rochat (1919), and Bourquin (1925). These discrepancies between species are no doubt dependent on the presence and amount of smooth muscle in the orbit.

Adler (1924) noticed a decrease in the formation of plasmoid aqueous following paracentesis during sympathetic stimulation in experimental animals. Thiel (1929) noted a short rise followed by a longer fall in both normal and glaucomatous human eyes; he also reported a bilateral effect on the intra-ocular pressure from stimulation of one sympathetic.

* Received for publication November 12, 1951.
† This work has been done with a grant from the Alexander Piggott Wehrner Memorial Trust Fund.

Colle and Duke-Elder (1931) produced a rise in the intra-ocular pressure of exsanguinated dogs by stimulation of the sympathetic, thus demonstrating that the initial rise in normal animals is due to contraction of smooth muscle in the orbit.

Yata (1930) stated that sympathetic section had no effect on the normal intra-ocular pressure but stimulation of the nerve lowered both intra-ocular pressure and blood pressure. Vidal and Malbran (1944) reported two cases of unilateral stellectomy in man in which the intra-ocular pressure was found to be equal and normal in the two eyes, 2 and 4 years respectively after operation.

Jaffe (1948), working with cats, showed that section of the sympathetic caused a fall in the intra-ocular pressure in the ipsilateral eye, which returned to normal in 2 or 3 days. He thought this fall due to loss of tone in the smooth muscle of the orbit.

Schmerl and Steinberg (1949) found that stimulation of the superior cervical ganglion caused a lowering of the intra-ocular pressure from 7 to 11 mm. Hg in rabbits. Davson and Matchett (1951) reported that section of the sympathetic in rabbits is sometimes followed by a large rise in the intra-ocular pressure which subsides within 30 to 60 min. Stimulation of the cut peripheral end caused a fall in the intra-ocular pressure.

In the majority of the above experiments, simultaneous blood-pressure records have not been done, and the intra-ocular pressure has been measured by a Schiötz or other type of indirect tonometer. We have attempted to obtain more accurate measurements of changes in the intra-ocular pressure of both eyes and simultaneous blood-pressure records of the result of section and stimulation of the pre-ganglionic cervical sympathetic nerve.

Methods of measuring the intra-ocular pressure fall into two groups: direct measurement by the insertion of a needle into the anterior chamber, and tonometric methods. Many workers have relied on repeated readings of the tension with a Schiötz type tonometer, and while this may be a useful method in long-term experiments and when large pressure changes are being measured, it is not sufficiently reliable for small changes and has the additional disadvantage that repeated readings tend to massage fluid out of the eye and thus to reduce the intra-ocular pressure.

We have therefore used the method of direct measurement, which allows continuous recording over several hours, if necessary. Details of this technique were extensively discussed as early as 1868 by von Hippel and Grünhagen. To maintain accuracy, the main factors to consider are:

(1) External pressure on the globe on the insertion of the needle must be small; for this purpose the needle must be sharp.

(2) There should be no loss of aqueous on insertion of the needle.

(3) The volume displacement of the needle on insertion should be small; in our own experiments it was never more than 1.2 µl. According to Wessely (1908), this increase of volume in the eye of a rabbit with a pressure of 20 mm. Hg will result in an increase of that pressure by about 1 mm. Hg.

(4) The movement of the rubber membrane of the manometer should likewise be small; in our apparatus the volume change, as measured directly by a micrometer syringe, was only 0.018 ml. for movement from 20 to 50 cm. saline, *i.e.*, 0.6 µl. per cm. saline, assuming the membrane to move in direct proportion to the volume change (which was practically the case).

Methods

The animals were anaesthetized with nembutal, 1½ gr. per lb. bodyweight, intraperitoneally. The sympathetic nerves between the middle and superior cervical ganglion were dissected out on both sides of the neck. The right femoral artery was next isolated and cannulated, using a siliconed glass cannula of the usual design, the blood pressure being recorded by a manometer of similar design to that used for the intra-ocular pressure but with a heavier gauge rubber membrane.

The intra-ocular pressure was recorded by inserting into the anterior chamber a No. 12 hypodermic needle connected by narrow polythene tubing to a manometer of the type described by Davson and Purvis (1950). Pantocaine 2 per cent. was instilled into the eyes before inserting the needles, as a rapid rise of intra-ocular pressure was seen to follow in a few cases if no local anaesthetic was used. The manometer system was filled with normal saline, and at the moment of insertion of the needle a reservoir connected to the manometer was adjusted to give a head pressure of 20 cm. saline—the tap being closed again as soon as the needle was in place.

The movement of beams of light reflected from the mirrors of the manometers was recorded on a moving film in a specially designed camera. See Figs 1 and 2.

When the intra-ocular pressure had reached a steady level in each eye, one sympathetic nerve was cut. The second sympathetic was left intact in some experiments and cut after an interval of about 10 min. in others. Stimulation was effected with an electronic square-wave generator (Attree, 1950 : oscillator circuit of Fig. 2, and pulse generator of Fig. 3) using 4 volts, 1 millisecond pulse width, and 50-cycle frequency. The duration of the stimulus is shown on the tracings.

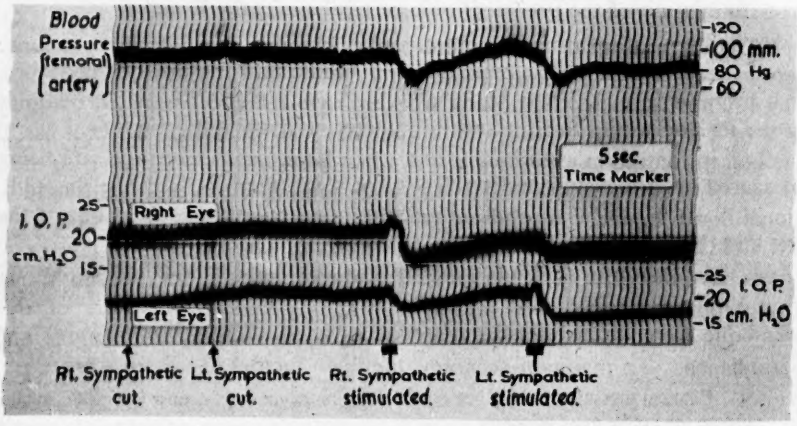

FIG. 1.—Section and stimulation of cervical sympathetic nerve in Cat 40.

Simultaneous record of the blood pressure in the femoral artery and of the intra-ocular pressure of each eye. The broken vertical lines are spaced at intervals of 5 sec. The immediate short rise of the ipsilateral intra-ocular pressure on stimulation is muscular in origin. Thereafter there is a fall in both eyes on unilateral stimulation of the sympathetic, due partly to the fall in general blood pressure and partly to local events in the eye. The difference between the fall in the ipsilateral and contralateral eye indicates the change due to local events.

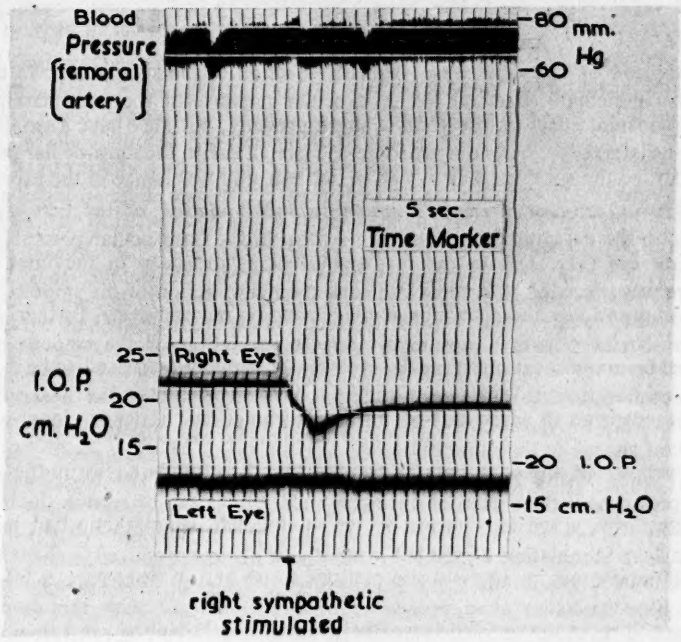

FIG. 2.—Stimulation of cervical sympathetic nerve in the rabbit.
Simultaneous record of the blood pressure in the femoral artery and of the intra-ocular pressure of each eye. There is no change in the blood pressure, and a fall in the ipsilateral eye is due solely to changes in the intra-ocular circulation.

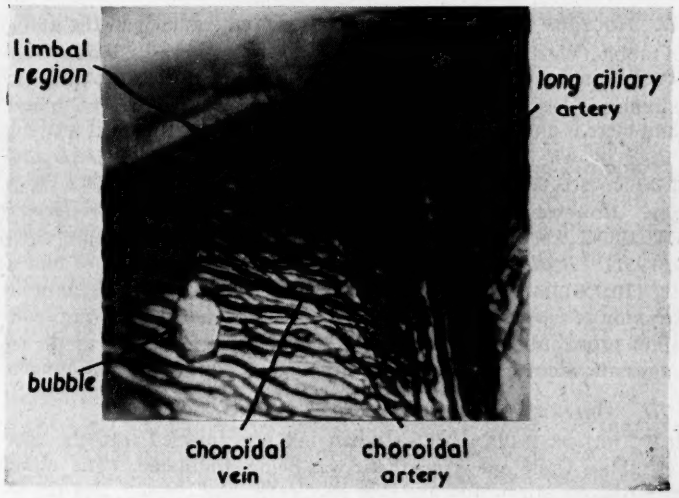

FIG. 3.—Photograph of choroidal vessels near limbus, together with a long posterior ciliary artery seen through the cleared sclera after injection of Indian ink into the carotid artery. The blob is an artefact due to a bubble in the oil.

Results

PART I

(*a*) SECTION OF CERVICAL SYMPATHETIC.—Section of the sympathetic in the cat has little immediate effect on the intra-ocular pressure of the contralateral eye, and no constant effect on the general blood pressure, but may have a small effect on the ipsilateral eye. In nine experiments, a small rise in the intra-ocular pressure was recorded in four eyes, a small fall in one eye, and no change in the other four.

(*b*) STIMULATION OF EITHER SYMPATHETIC.—Stimulation of the cervical sympathetic in the cat caused in every case a drop in the intra-ocular pressure in the ipsilateral eye (Fig. 1). In the majority of cases the drop in the intra-ocular pressure was preceded by a rapid rise caused by contraction of the smooth muscle in the orbit and lids and retraction of the nictitating membrane. A further drop in the intra-ocular pressure, presumably due to relaxation of the smooth muscle, occurred on many occasions immediately after the stimulation ceased, to be followed by a slower return to the pre-stimulation level. A fall in the general blood pressure occurred in seven out of thirteen stimulations, a rise in four, and no significant change in the other two.

The pressure in the contralateral eye was found to follow passively the general blood pressure; it thus changed during stimulation, as can be seen in the tracings. This effect was noted in all cases in which the right sympathetic had been cut previously. Stimulation of the left sympathetic always produced a change in the general blood pressure, in eight stimulations a rise and in three cases a fall.

The blood-pressure changes were probably associated with the number of depressor fibres in the cervical sympathetic nerve, a fall of blood pressure occurring when depressor fibres were included. In the absence of depressor fibres, a rise of blood pressure might occur reflexly due to reduction of blood flow to the head. In the rabbit, stimulation of the cervical sympathetic produced a fall in intra-ocular pressure, the initial rise seen in the cat being absent (Fig. 2).

PART II. AQUEOUS VEINS.—These can be observed regularly in the limbal circulation of rabbits (Weekers and Prijot, 1950; Greaves and Perkins, 1951). We watched the effect of stimulating the cervical sympathetic on the appearance of these vessels.

If a stimulus of less than 5 volts is used, a decrease in calibre of the blood vessels is seen and there is an apparent increase in the flow of aqueous. If a stimulus of 5 volts is used, the whole limbal region becomes avascular and it is impossible to tell whether aqueous is still flowing along the aqueous veins or whether these vessels are empty. If, however, Evans blue, a non-particulate dye, is introduced into the anterior chamber, it soon appears in the aqueous veins of these animals (Greaves and Perkins, 1951). If the sympathetic is now stimulated, the stream of blue aqueous can be seen to continue flowing even when the other vessels contain little or no blood.

Constriction of the arterioles of the anterior ciliary system following sympathetic stimulation probably causes a lowering of the venous pressure in the collecting vessels, thus allowing an increase in the drainage of aqueous *via* the aqueous veins.

PART III. CHANGES IN CHOROIDAL CIRCULATION

(*a*) INJECTION OF INDIAN INK.—Indian ink was injected into the innominate artery of rabbits while one sympathetic was being stimulated. The animals were killed immediately afterwards, the eyes enucleated and opened, and the choroidal circulation and ciliary region examined under a slit-lamp microscope. The in-

jected vessels were seen to be contracted on the side of the stimulation; this was most marked in the region of the ciliary body.

(*b*) DIRECT OBSERVATION OF CHOROIDAL CIRCULATION.—During the course of observations on the aqueous veins of rabbits, it was noticed that, unless the eye was kept moist, exposed scleral regions tended to appear black, because an increase in transparency allowed the choroidal pigment to show through.

In albino rabbits with no choroidal pigment, it was thought that the choroidal vessels might be made visible. After some trial experiments, it was found that an excellent view of the choroid could be obtained by the following technique:

In an anaesthetized albino rabbit the conjunctiva is dissected off the area of sclera to be examined. Sutures are inserted in the recti muscles to hold the eye in the desired position. A stream of warm air is now directed on to the bare sclera and in about 5 minutes the area shows a red patch indicating that the sclera is now transparent. A drop of oil on this surface improves the optical conditions, and bright focal illumination through the pupil to illuminate the area of choroid involved allows the choroidal vessels to be examined in detail using the binocular microscope of a Haag-Streit slit lamp.

With this technique the long posterior ciliary arteries can be seen running forward to the root of the iris where they divide to form the major circle of the iris. A much convoluted network of veins can be seen to accompany them (Fig. 3). The vortex veins are easily recognized and the marked constriction during their passage through the sclera is noted. Branches of the short ciliary arteries appear as fine vessels running between the choroidal veins, crossing under and over them. These arterial branches are continued right up to the formation of the vortex vein, and some give the appearance of joining a vein directly. We have not been able to demonstrate any direct arterio-venous connection. On several occasions, by injection of Indian ink into the carotid, an apparent connection has been shown to be an illusion caused by the artery disappearing beneath the vein.

It is certain, however, that the flow from artery to vein is extremely rapid as a substance such as Indian ink injected into the carotid appears in the choroidal veins as soon as it can be seen in the arteries. In such experiments it is interesting to note that with the rectus muscles detached, although the whole circulation of the choroid and iris is easily injected, no injection material appears in the aqueous veins or in the episcleral veins unless a higher pressure is used. This suggests that there is little connection between the two vascular systems within the eye. In confirmation of this, it is found that Evans blue injected under pressure into the anterior chamber rapidly fills the aqueous veins and all the episcleral veins, but does not enter the choroidal circulation. These experiments confirm the investigations of Seidel (1924) and Kiss (1943), who found that indigo, carmine, and Indian ink injected into the anterior chamber filled the ciliary, intrascleral, and episcleral veins, but did not enter the iridic, choroidal, and vortex veins.

It therefore seems likely that the drainage of aqueous from the anterior chamber is confined to the episcleral circulation and that drainage into the choroid, if it occurs at all, is minimal.

STIMULATION OF CERVICAL SYMPATHETIC

If the choroidal circulation is watched by the above method while the sympathetic nerve in the neck is stimulated, no changes in the visible vessels can be seen. There is a lightening of the background colour between the main vessels, which is presumably due to constriction of the choroidal capillaries. A similar change can be produced by the intravenous injection of adrenaline in doses of 20 to 200 γ.

If the circulation is slowed down by partial occlusion of the ipsilateral carotid, the flow in the choroidal veins becomes easily visible, and, under these conditions, stimulation of the sympathetic results in a further slowing of the stream.

This effect is not nearly so striking as the changes which occur in the episcleral vessels. It is possible that the drying of the sclera interrupts the flow of nervous impulses in the sympathetic fibres, for it was noted that pupillary dilatation was less marked in the segment of the iris related to the area under observation. In an attempt to obviate such an effect, a lamellar resection of the sclera was done before drying. The thin layer remaining was almost transparent and required very little drying before a good view of the choroid could be obtained. Under these conditions, good pupillary dilatation was obtained on sympathetic stimulation, but the changes in the circulation in the choroid were not appreciably increased.

It therefore seems probable that, apart from some effect on the chorio-capillaris, the sympathetic system does little to control the choroidal blood vessels.

Summary

(1) Section of the cervical sympathetic nerve had little effect on the intra-ocular pressure in the cat.

(2) Stimulation of the cervical sympathetic nerve in the cat caused an initial rise followed by a fall in intra-ocular pressure. The initial rise is probably due to contraction of smooth muscle in the orbit.

(3) Stimulation of the cervical sympathetic caused an apparent increase in the drainage of aqueous fluid into the aqueous veins of the rabbit.

(4) Stimulation produced some contraction of the chorio-capillaris but no marked changes in the larger choroidal vessels. The vessels were observed *in vivo* by dehydrating the sclera of albino rabbits. A similar indeterminate result followed the intravenous injection of adrenaline.

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Brit. J. Ophthal. (1952) 36, 265.

ANATOMICAL STUDY OF SCHLEMM'S CANAL AND AQUEOUS VEINS BY MEANS OF NEOPRENE CASTS*

PART II. AQUEOUS VEINS (CONTINUED)

BY

NORMAN ASHTON

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AN anatomical study of six aqueous veins by means of Neoprene casts has already been reported (Ashton, 1951); it was shown that two arose directly from Schlemm's canal while the remaining four communicated with it indirectly *via* anastomotic branches between the superficial and deep scleral plexuses. All the aqueous veins were of the striated or laminated variety. It has now been possible to study the anatomy of a pure aqueous vein by the same technique and the purpose of this paper is to report the findings.

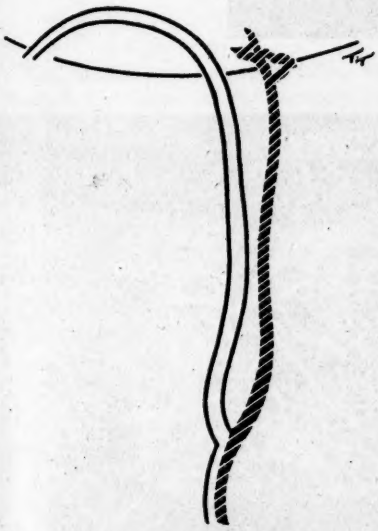

FIG. 1.—Diagram of pure aqueous vein made before operation. Note that it joins with an ordinary vein to form a laminated vein. The vessel was marked with a tantalum wire loop.

MATERIAL AND TECHNIQUE

The patient was a male aged 58 years (Case of Mr. C. Dee Shapland); enucleation was performed for a malignant melanoma of the posterior choroid. An unusually large pure aqueous vein was identified near the limbus at 8 o'clock and a drawing was made (Fig. 1); immediately before enucleation a tantalum wire suture was tied loosely around the vessel.

After operation the anterior part of the eye was removed and a radial cut to the centre of the cornea was made at 12 o'clock.

* Received for publication February 8, 1952.

Neoprene coloured red with carmine was injected into Schlemm's canal and the aqueous vein filled with Neoprene ; the specimen was then digested in pepsin followed by trypsin and after examination it was mounted in gelatin (Figs 2 and 3).

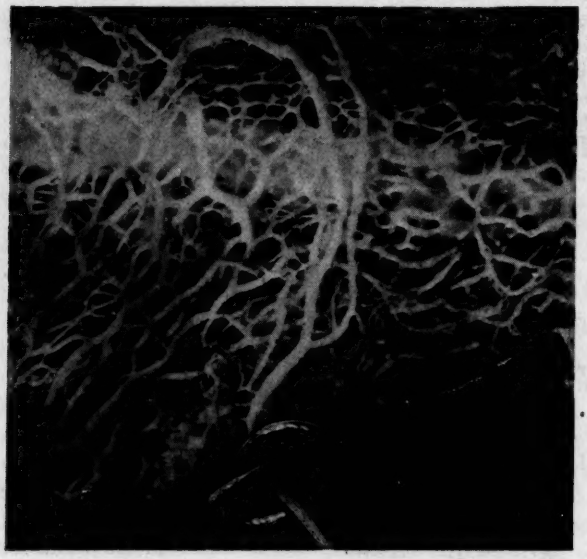

FIG. 2.—Neoprene cast of Schlemm's canal and limbal vessels showing sector containing marked aqueous vein. The tantalum wire loop is still to be seen *in situ*. Details of the origin of the vessel are shown in Figs 3 and 4. × 20.

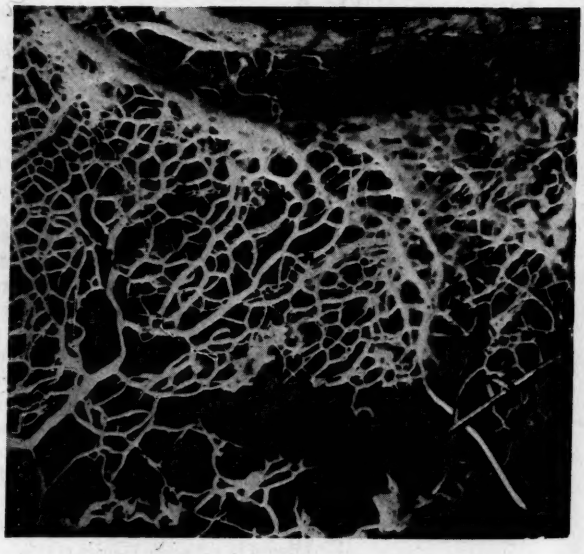

FIG. 3.—Neoprene cast shown in Fig. 2. The superficial vessels containing the aqueous vein are now deflected downwards to show the direct connections between the vein and the canal. The exact structure can be made out only by microdissection and the details are shown in Fig. 4. × 14.

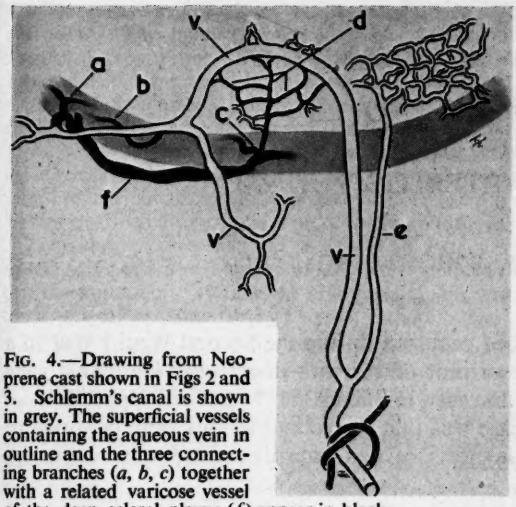

FIG. 4.—Drawing from Neoprene cast shown in Figs 2 and 3. Schlemm's canal is shown in grey. The superficial vessels containing the aqueous vein in outline and the three connecting branches (*a*, *b*, *c*) together with a related varicose vessel of the deep scleral plexus (*f*) appear in black.

FINDINGS

Micro-dissection of the Neoprene cast (Fig. 4) showed that the pure aqueous vein (*v*) did not itself branch out of the canal but communicated with it directly *via* three channels (*a*, *b*, *c*), two of which (*a* and *b*) opened directly into the vein, while the third (*c*) broke into several small twigs (*d*) before anastomosing with the arch of the vein. The connecting branches (*a* and *c*) communicated with each other at their origin through a large varicose vessel of the deep scleral plexus (*f*). The venous limb (*e*), which in life contained only blood, was not connected, in its immediate vicinity, either directly or indirectly with the canal.

DISCUSSION

Thus in the seven aqueous veins we have studied, whether they were pure or striated, the source of the aqueous was undoubtedly from Schlemm's canal and their connecting branches varied only in detail. It can therefore be concluded that whether or not a vessel contains aqueous, blood, or a mixture of aqueous and blood, is to a certain extent fortuitous, in that it depends upon the quantity of aqueous inflow permitted by the almost infinite variation in the minute anastomotic connections between Schlemm's canal and the superficial vessels, and upon the opposing venous blood pressure within the receiving vascular bed. Consequently, it is not difficult to understand why the aqueous vein here described, being both a large vessel and having three direct tributaries from Schlemm's canal, should have been, in the early part of its course, a pure aqueous vein.

It is a pleasure to acknowledge my indebtedness to Mr. Arthur Lister who kindly identified and sutured the aqueous vein.

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(This study is to be continued in a future issue of this Journal.)

Brit. J. Ophthal. (1952) **36**, 268.

CASE NOTES

PERI-ARTERITIS RETINAE*

BY

A. M. WRIGHT THOMSON

Glasgow

THE case about to be described occurred during the Second World War in a Royal Canadian Air Force warrant officer shot down over Germany. He was taken prisoner and was first seen in Stalag 344, Lamsdorf, Upper Silesia. The unusual feature of his case was that the retinal lesions were confined to the retinal arteries and a diagnosis of peri-arteritis retinae was made, for want of a better name.

Case Report

Warrant Officer C., aged 26, was first seen on March 31, 1944, when he complained that he had been seeing black spots in front of both eyes for the preceding 2 months. He had noticed no signs of inflammation in the eyes.

Examination.—Visual acuity in the right and left eyes was 4/4.5. Each eye had pigmented spots on the anterior surface of the lens and vitreous opacities. Ophthalmoscopic examination showed multiple small white areas on the retinal arteries (Figs 1 and 2), more marked in the left eye. The retinal veins in both eyes were dilated. An investigation was made to see whether there were any foci of infection elsewhere in the body.

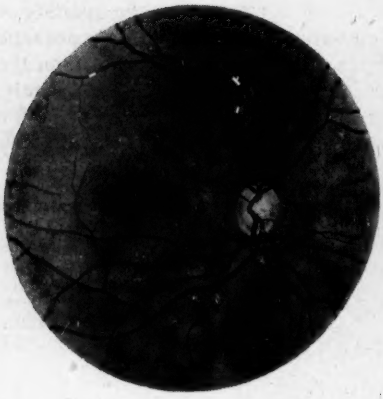

FIG. 1.—Right eye, 23.4.44.

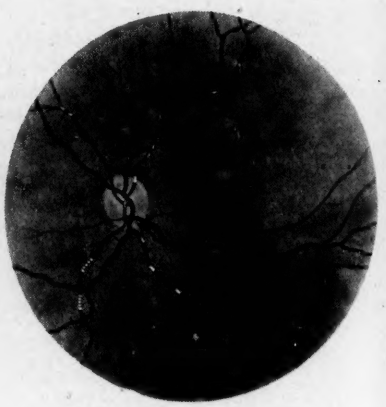

FIG. 2.—Left eye, 23.4.44

White plaques on course of arteries.

* Received for publication December 17, 1951.

The blood sedimentation rate was 3 after one hour and 15 after two hours. The urine was clear. The blood pressure and blood count were normal. The Wassermann reaction was negative. *X* ray of chest showed no abnormality and an intradermal tuberculin test was negative. He had some stuffiness of the nose, and examination by Capt. A. F. Stallard, R.A.M.C., revealed muco-purulent discharge from the middle meatus on the left side and a little less from the superior meatus on the same side. He was given Argyrol packs and douches and later ephedrine and menthol drops. An *x* ray examination showed that both antra were probably opaque. The patient was later referred to a German hospital for examination where a detailed investigation was again carried out, including examination of the sputum for tubercle bacilli, with negative result.

The clinical picture was therefore one of old iridocyclitis with a few posterior synechiae and vitreous opacities, along with multiple white plaques on the retinal arteries. Some of these appeared to encircle the artery like a cuff, while others appeared to be applied to the side of the artery (Fig. 2, upper temporal artery).

Clinical Course.—The fundi were examined at intervals and it was found that the white plaques tended to become absorbed. Four months after the first examination (Figs 3 and 4), fluffy pink areas began to make their appearance on the course of several of the retinal arteries. These were fainter in the left eye (Fig. 4, lower nasal artery) and more obvious in the right (Fig. 3, lower nasal artery). At the lower extremity of the right lower nasal artery a fluffy patch was visible through which sheathing of the underlying artery could be seen (not shown in Fig. 3). No white plaques were visible in the right eye, but two were still visible on the course of the left upper temporal artery in the area of the optic disk (Fig. 4). In both eyes small, bright yellow, circular dots were beginning to make their appearance on the course of the retinal arteries at sites roughly, but not necessarily, corresponding to the former position of the white plaques.

FIG. 3.—Right eye, 19.8.44

FIG. 4.—Left eye, 19.8.44

Yellow refractile circles and pink fluffy areas on course of some arteries.

Seven weeks later the appearances tended towards recovery (Figs 5 and 6) but a fresh fluffy pink patch could be seen on the course of the left upper temporal artery (Fig. 6). In the right eye several small, bright yellow circles could be seen outside the lower branch of the superior temporal artery (Fig. 5).

About nine weeks later the left eye showed two small fresh white circular areas on the course of the lower temporal artery (not shown in the diagrams). The white plaques on the course of the left upper temporal artery in the area of the optic disk were still

visible about 10 months after the first examination when it became impossible to follow up the case further.

FIG. 5.—Right eye, 10.10.44

FIG. 6.—Left eye, 10.10.44

Yellow refractile circles, fewer in number in left eye, but occurring outside one branch of temporal artery in right eye. One pink fluffy area can be seen in each eye. Only left eye still shows two white plaques in optic disk area.

Discussion

Peri-arteritis is a much rarer condition that periphlebitis in the eye and, in this case, appeared to be a complication of iridocyclitis. It is well known that periphlebitis can occur as a spread backwards from iridocyclitis but peri-arteritis is not such a common complication. It is, of course, possible to have the two conditions occurring in an eye simultaneously, but, in the present case, apart from some dilatation of the veins, the changes were confined to the arteries and no haemorrhages were present.

A study of the changes which have occurred brings out the following points:

(1) The first changes seen were white plaques, sometimes apparently encircling the artery like a cuff and sometimes apparently applied to the side of the artery.

(2) Small refractile circular areas appeared on the course of the arteries; these were apparently at the former site of a white plaque, but not necessarily so.

(3) Pink fluffy areas appeared on the course of the arteries, some of which were succeeded by refractile yellow circles as before.

(4) Although the majority of the white plaques disappeared there were still three small ones applied to the left upper temporal artery in the area of the optic disk after an interval of about 10 months.

The significance of the pink areas is not clear. They seem to indicate a small focus of activity of some kind and it would be attractive to suggest that they were the forerunners of the white plaques. Such a change, however, was not seen to occur. It is curious too, that, although the arterial

wall must have been damaged by the infective process, if such it be, no haemorrhages were seen to occur.

The question of aetiology is difficult. In recorded cases, tuberculosis has been regarded as a possible cause, and Muncaster and Allen (1939) have described a case which bears a striking resemblance to the present one. Their case followed a tuberculin test and it is interesting to note that it was associated with a generalized uveitis which, presumably, included iridocyclitis as in the present case. The case referred to is illustrated in Duke-Elder (1940), and it will be seen that the white plaques are smaller than those seen in the initial stages described above, but a few circular white areas of similar size did develop in the present case which do not appear in the illustrations. In addition, a fluffy patch can be seen on the artery at 6 o'clock in Muncaster and Allen's case which bears some resemblance to the pink fluffy patches described above.

Tuberculosis was considered to be a causal factor of the iridocyclitis and the peri-arteritis in the present case, but all investigations in this direction were, as already stated, negative.

The only other possible source of infection here was in the nasal air sinuses and an *x* ray of the skull showed that both antra were probably opaque. Although it is very difficult to determine the causal factor, it must be recorded that, under treatment of the nose with Argyrol packs and douches and, later, with ephedrine and menthol drops, the condition of both nose and eyes improved. This, however, was probably coincidental.

Summary

A case of peri-arteritis retinae apparently following an attack of iridocyclitis is described. The signs presented were white plaques and later pink fluffy patches on the course of the retinal arteries. No focal cause of these changes was found but the aetiology is discussed.

I am grateful to the Director of Medical Services and the Director of Public Relations, War Office, for permission to publish this paper.

My thanks are also due to Mr. G. Donald who copied my own original fundus drawings.

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Brit. J. Ophthal. (1952) 36, 272.

SCLERAL PLAQUES*

BY

BASIL GRAVES

London

THOSE scleral plaques which I have previously reported (Graves, *1937, 1939, 1941*) were in the nasal area of the sclera, with the exception that in one case which I had seen there was a faint suggestion of plaques in the temporal area also. As far as I am aware, Dr. P. H. Boshoff of Johannesburg was the first to report defined lateral (temporal) plaques. His communication (1942) was of particular interest because he reported inferior plaques in addition. Both temporal and inferior plaques would seem to be rare compared with nasal plaques (Culler, 1939). By way of completing my previous records I now submit details, with comparative measurements, of a case of pronounced plaques in both the nasal and the temporal areas of each eye.

Case Report

C. Y., a lady aged 84, who came to see me in 1944, was the first patient that I had seen with very noticeable plaques in both the nasal and the temporal areas. I made notes, meaning to publish them after the war, but these were mislaid and came to light only recently in some stored luggage.

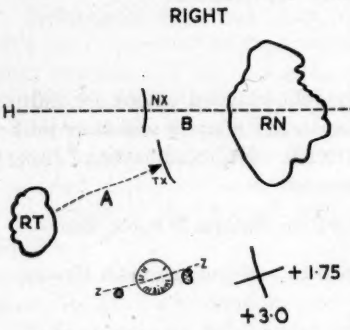

FIG. 1.—Position and relative sizes of plaques in right sclera.

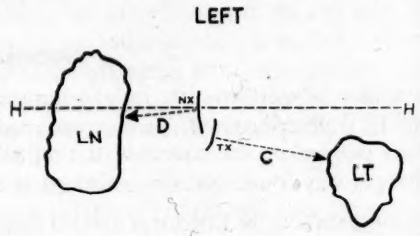

FIG. 2.—Position of plaques in left sclera.

The two accompanying diagrams (Fig. 1, right eye, and Fig. 2, left eye) have now been compiled from these notes. I submit these particulars mainly because they give measurements in keeping with my previous reports, but I regret that these measurements cannot here be stated in terms of millimetres, because in 1944 I was using a micrometer ocular which I have not used since and which has become mislaid in the interval. As the notes record the measurements only in terms of the units composing this ocular scale, and as at present I have no ready means of checking how many units in this ocular represented a millimetre, I can here only quote measurements in terms of these units (I have an impression from memory, however, that about 9 units represented one millimetre).

* Received for publication August 15, 1950.

In the two accompanying figures, HH represents a horizontal line through the centre of each cornea. The right temporal, the right nasal, the left temporal, and the left nasal plaques are represented by RT, RN, LT, LN, respectively.

In Fig. 1 (right eye) TX represents the nearest part of the limbus (temporal) and the line A represents its distance from the edge of RT. Similarly NX is the nearest part of the limbus (nasal) to the edge of RN, B being the distance between.

In Fig. 2 (left eye) the distances C and D have a corresponding significance.

In each of these figures, while the distance to the nearest part of the limbus (NX and TX) is proportionately indicated, the distance between the plaques themselves is much compressed by the omission of the equivalent of the diameter of the cornea.

Observations.—All four plaques were very dark and noticeable. Looked at by naked-eye observation, the middle of the right nasal plaque was at, or very slightly below, the mid-horizontal line HH; the middle of the left nasal plaque was a little below this line.

The horizontal measurement of RT at its widest part was 18 units, and the vertical 25 units. The horizontal measurement of RN was 38 and the vertical 50 units. Similarly, LN was horizontally 25 and vertically 48, and LT was horizontally 25 and vertically 30.

The distances A and C were 45 and 41 respectively; and B and D were 31 and 26 respectively.

In the right eye the retinoscopy under homatropine was as noted in Fig. 1 (with peripheral lens changes as indicated). The unaided vision of the right eye under homatropine was 6/18. With + 0.5 sph. and + 1.0 cyl., 25 to 30, the vision was 6/12 (the patient was deaf and testing was not easy). The line ZZ in Fig. 1, which represents a line drawn through the centre of the cornea, just touches the upper edge of each plaque. There were opaque nerve fibres above the right optic disk.

The left eye had mature cataract.

It will be noticed that in each eye the nasal plaque was nearer to the limbus, longer, and situated higher than was the temporal plaque. The vertical relationship of the plaques to the mid-horizontal line (HH) was proportionately as drawn here in relation to their size. But to save space in these diagrams the horizontal distance of the plaques from each other is compressed by approximately the amount of the diameter of the cornea, as is indicated by the relationship of NX and TX (the limbus) in each diagram.

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Brit. J. Ophthal. (1952) **36**, 274.

CORRESPONDENCE

VON GRAEFE *versus* KERATOME

To the Editorial Committee of the

BRITISH JOURNAL OF OPHTHALMOLOGY

DEAR SIRS—In Mr. Neubert's letter in your December issue (*British Journal of Ophthalmology*, **35**, 798) he writes as if it were impossible to suture an eye that has been incised with a knife. This is of course not so, but nevertheless I was much interested to read his letter, although I cannot agree with his statements. In 1947 I was able to spend two months in New York watching Mr. Castroviejo's work. On my return to India I adopted his technique and have used it for the last 350 cataract extractions which I have done. I work without an assistant, but I find no difficulty in so holding the conjunctival flap that I can watch the tip of the keratome. Similarly, when enlarging the incision with curved scissors, the blades can be watched within and without the anterior chamber, although after a time it is often not necessary to watch the blade within the chamber since its position can be felt. I have never had to use a vectis because of an oblique incision.

This technique admittedly takes a little longer; my first case took about an hour but now twenty minutes is about the average time from starting the conjunctival incision to tying the last stitch. It is a very satisfactory procedure and one feels that one has completed a proper surgical technique with an incision adequately sutured, which is of great importance in a jungle hospital where we have insufficient staff to watch all the patients all the time. On one occasion I found an old man climbing the hospital fence on the morning following his operation, with, I am glad to say, no untoward results. This would not have been so in the days when I used a knife and did not suture my incisions.

Yours faithfully,

G. D. LEHMANN.

HERBERTPUR MISSION HOSPITAL;
HERBERTPUR P.O.,
DROT DEBRA DUN,
UNITED PROVINCES, INDIA.

February 11, 1952.

METHONIUM COMPOUNDS IN OPHTHALMIC SURGERY

To the Editorial Committee of the

BRITISH JOURNAL OF OPHTHALMOLOGY

DEAR SIRS—We have read the article by B. W. Rycroft and G. J. Romanes in your January issue reporting the use of methonium compounds and general anaesthesia in ophthalmic surgery (*British Journal of Ophthalmology*, **36**, 29) with a little disquiet.

Surely the only reason for using this technique is for the direct benefit of the patient; and in every operation any advantage gained must be balanced against the added risk run. It appears from this report that the main objective is to facilitate surgery and to produce a better result. It is admitted that the operations mentioned are not impossible of performance without this agent " but all are rendered more easy and accurate with it ".

The method reviewed is still in the stage of investigation. The factor of danger to the patient has been by no means fully evaluated. At present, each new finding will allow the existing limits of the technique to be pushed out a little further. So is experience being gained.

Many points in this article must still be considered to be in the melting pot. Only with the gaining of much more experience can the method become accepted, or even maybe rejected.

We feel most strongly that it cannot be too often repeated that this technique is still in its experimental stages.

Yours faithfully,

RUSSELL M. DAVIES.
A. A. MASON.

PLASTIC SURGERY AND JAW INJURY CENTRE,
QUEEN VICTORIA HOSPITAL,
EAST GRINSTEAD, SURREY.

February 20, 1952.

CONGENITAL PIGMENTATION OF THE CORNEA

To the Editorial Committee of the

BRITISH JOURNAL OF OPHTHALMOLOGY

DEAR SIRS—I was much interested to read in your February issue Eugene Chan's well-reasoned explanation of the anomaly of congenital pigmentation of the cornea (*British Journal of Ophthalmology*, **36**, 104).

Some time ago I was struck by the frequency with which one sees corneal and subconjunctival pigment deposits among Gold Coast Africans. In an attempt to assess this and other clinical findings, which I thought were variations of the physiological normal, I examined the eyes of two hundred African school children. These were all attending Accra schools and were apparently healthy.

My notes show that I recorded the presence of " subepithelial pigmentation of the cornea " in 192 of these children, and subconjunctival pigmentation in 198 of them. The condition was bilateral, and the appearance and location of the corneal pigment were exactly similar to those in the case described by Chan. The irides of the African children were deeply pigmented, but in those who had no corneal pigmentation the skins were pale; this pallor was found to be associated with a history of European ancestry within the previous few generations.

Yours faithfully,

JOHN W. R. SARKIES.

OPHTHALMIC DEPARTMENT,
GOLD COAST HOSPITAL, ACCRA.

March 6, 1952.

ALBINOS WITH NORMAL OFFSPRING

To the Editorial Committee of the

BRITISH JOURNAL OF OPHTHALMOLOGY

DEAR SIRS—I should like to add a few remarks to Mr. Trevor-Roper's article in your February number about a very interesting pedigree, in which two generalized albinos had three children with normal pigmentation and even dark brown irides (*British Journal of Ophthalmology*, **36**, 107).

This case report is as yet unique and may be explained in one of the following ways:

(*a*) The father is a case of albinoidism or of incomplete generalized recessive albinism, having slightly darker hair than the wife. The stroma of his iris has no pigment (?) and his hair colour is nearly white, because he belonged to a very fair blue-eyed normal type to which the albinoidism gene was added. The mother is a case of complete generalized recessive albinism combined with genes for dark complexion. If this were true, it would be proved that recessive albinism and recessive albinoidism are not situated at the same locus of the chromosome and are therefore not polyalleles.

(*b*) One of the parents is a case of dominant complete albinism and the other a case of recessive albinism, and their gene deficiencies occupy different loci. This hypothesis is not very probable because no child has inherited this dominant gene nor was there an affected person among the ascendants of either of the parents. It cannot quite be excluded, however, for the parent with dominant albinism may be the result of a mutation and it is only accidental that this has not been transmitted to one of the children.

(*c*) Both parents suffer from complete recessive albinism, due to different genes, which possibility is already known in plants and animals.

(*d*) The paternity is dubious. I think this may be excluded as this possibility was not mentioned at all.

In any event, the science of genetics is much indebted to Mr. Trevor-Roper, though geneticists will not easily agree with the suggestion that the Mendelian laws have been violated. I might add that I have found in the Netherlands very few exceptions to the rule that heterozygotes for albinism have a translucent iris (partially or totally). This has been verified by many contemporary workers, but is difficult to demonstrate in dark brown irides.

Yours faithfully,

P. J. WAARDENBURG.

VELPERWEG 22, ARNHEM,
NETHERLANDS.

February 19, 1952.

Brit. J. Ophthal. (1952) 36, 277.

BOOK REVIEWS

Text-book of Refraction. By E. F. Tait. 1951. W. B. Saunders, London. Pp. 418, 95 figs. (40*s*.)

The title of this book gives little indication of the scope of the subjects covered in its text. The author emphasizes in his preface that his object was to produce a book in which refraction and the ocular neuromuscular abnormalities were considered in close relationship with their underlying physiological principles. As a teacher of many years' standing, he has taken advantage of both clinical and classroom experience in the selection of his material. At the same time, where modern advances have, in his opinion, rendered earlier methods of observation and teaching obsolete, reference to these more orthodox views has been omitted or curtailed. The result is a volume in which the practical consideration of refraction tends to take second place to a detailed description of the physiological processes involved in the production and interpretation of visual images.

It is assumed that the reader has a sound basic knowledge of the anatomy and physiology of the eye, and of the neuromuscular mechanism in ocular movements. Geometric optics is omitted altogether, except where the optical principles of a method of examination or of an instrument are explained in the course of describing a particular technique, and it is important for the reader to be already acquainted with both geometric and physiological optics. This is somewhat unusual in a text-book of refraction, but has the great advantage that it enables the author to devote more space to subjects which are dealt with in less detail in similar books, and which, strictly speaking, do not normally come within the scope of such a text-book.

About half the book is devoted to the anomalies of accommodation and refraction, the methods of refraction, and the interpretation of the objective and subjective findings, but these apparently closely related problems are placed before and after the remaining half of the text, which deals in meticulous detail with the physiological and psychological aspects of binocular vision and ocular muscle anomalies. By way of contrast, eight chapters are devoted to the theoretical consideration of ocular movements, and only as many pages to the practical application of orthoptics to the problems of heterotropia and heterophoria.

Apart from the curious use of the word " astigmia " where one is more accustomed to see " astigmatism ", the description of the anomalies of refraction and accommodation is orthodox, and is adequate for the student approaching the subject for the first time. The chapters devoted to the methods of refraction include static and dynamic retinoscopy and optical instruments for the measurement of corneal curvature, but among these no mention is made of the Fincham coincidence optometer. Helpful information is given on the use of cycloplegics and mydriatics, and there is a chapter which includes a description of subjective methods in patients with subnormal vision, and a consideration of the optical devices available to give the maximum visual acuity in such cases. The last chapter outlines the author's own system of investigating a refraction case, and of interpreting and correlating the data thus obtained.

This book deals in a quite unorthodox way with the subject of refraction, and lays considerably more emphasis on the contribution of muscle balance to the problem of

visual comfort than one would expect. Its title might justifiably include some reference to its treatment of this part of the subject. Provided that the student for whom it is intended first becomes acquainted with the basic principles involved, he will find that the author's integration of the problems of refraction with those of the muscular anomalies forms an interesting approach to both subjects. The book itself is well produced, and adequately illustrated, and the appearance of yet another text-book on an already familiar subject can easily be justified by the author's sincere efforts to help the student better to understand the relative importance of the many factors which must be taken into account in the apparently simple process of prescribing a pair of glasses.

Synopsis of Ophthalmology. By J. L. C. MARTIN-DOYLE. 1951. John Wright, and Sons, Bristol. Pp. 246. (20*s*.)

A synopsis is the least satisfactory of all text-books, for it can only draw the accepted outlines of its subject and leave the finer shades and subtleties to others. It cannot be said, however, that the outlines of "A Synopsis of Ophthalmology" are accepted or acceptable: it is doubtful whether the author could find support for his classification of retinitis proliferans as a disease of the vitreous; anyone who has applied surface diathermy to a retinal dialysis knows that visible coagulation takes place in the retina; simple glaucoma has no characteristic prodromal symptoms nor is the tonometer a guide to classification; trephining is neither the only nor the best operation for buphthalmos; trauma is only one aetiological possibility in haematoma of the lids; and mixed tumours of the lacrimal gland have long since ceased to be regarded as endotheliomatous. It is presumptuous to imagine that ophthalmology can be usefully discussed within the confines of 238 pages. The experienced ophthalmologist who can be induced to read them will certainly find much to irritate, and the student working for a higher diploma should be similarly affected.

NOTES

PAN-AMERICAN ASSOCIATION OF OPHTHALMOLOGY

THE Proceedings of the Fourth Congress of the Pan-American Association of Ophthalmology, which was held in Mexico D.F. in January, 1952, will be ready for distribution early in June. There will be three volumes of about 500 pages each, most of the contributions being in English. Each volume will cost $20 U.S.A. All enquiries should be addressed to Dr. Luis Sanchez Bulnes, Gomez Farias 16, Mexico D.F., Mexico.

INTERNATIONAL CONGRESS OF MALARIA AND TROPICAL MEDICINE, 1953

THE fifth international congress of malaria and tropical medicine will be held from September 2 to 8, 1953, in Istanbul, Turkey.

In addition to Malaria, sections are planned on the following subjects: Trypanosomiasis, Virus Diseases, Rickettsial Diseases, Schistosomiasis, Filariasis, Nutrition.

The President of the Turkish Organizing Committee is Professor Tefvik Saglam. All communications should be addressed to the Secretary-General, Professor Ihsan Sükrü Aksel, Beyoglu Tunel Meydani No. 2, Istanbul, Turkey.

INTERNATIONAL CONGRESS OF OPHTHALMOLOGY, 1954

THE XVII International Congress of Ophthalmology will take place at the Waldorf-Astoria Hotel in New York City in the week beginning September 12, 1954. Dr. Bernard Samuels (*New York*) will serve as President, with Dr. John H. Dunnington (*New York*) as Vice-President, and Dr. William L. Benedict (*Rochester, Minn.*) as Secretary-General.

It is tentatively planned that the annual meeting of the American Academy of Ophthalmology and Otolaryngology should take place at the Waldorf-Astoria Hotel in the following week.

Further information will be published from time to time. All correspondence should be directed to the Secretary-General, Dr. William L. Benedict, 100, 1st Avenue Building, Rochester, Minnesota, U.S.A.

UNIVERSITY OF GLASGOW

DEPARTMENT OF OPHTHALMOLOGY

DURING May, 1952, a series of meetings will be held on Wednesdays at 8 p.m. A discussion will follow the main paper.

May 7. Films of ophthalmic operations.
May 14. Dr. J. N. Tennent.—"A Visit to India".
May 21. Dr. Paul Bacsich.—"Experimental Retinal Grafting".
May 28. Dr. Fergus Campbell.—"Night Myopia".

HONOURS

MR. G. T. WILLOUGHBY CASHELL, F.R.C.S., Ed., has been elected to the Fellowship *ad eundem* of the Royal College of Surgeons of England.

MR. A. J. BOASE has been elected to the Fellowship of the Royal College of Surgeons of England.

BRITISH EMPIRE SOCIETY FOR THE BLIND

APPOINTMENT OF OPHTHALMIC SURGEON

Applications are invited for the appointment of an experienced ophthalmic surgeon to conduct the first full-scale survey of eye diseases, and research into their prevention, to be undertaken in Nigeria and the Gold Coast. Salary of £2,000 per annum on a three years' contract determinable after one year, plus three months' annual leave. Outfit allowance, free passages, rent-free accommodation.

A simultaneous entomological survey is to be undertaken into the factors concerning onchocerciasis and other insect-borne diseases. Both surveys are being provided with mobile units and will work in co-operation. The ophthalmic survey will commence in the Northern Territories of Gold Coast in November, 1952, and will take three years.

Six copies of applications (stating age, qualifications, experience, previous appointments, and publications) should reach the Secretary, British Empire Society for the Blind, 53, Victoria Street, London, S.W.1, within 21 days of the date of appearance of this notice.

OBITUARY

CHARLES SCOTT SHERRINGTON

By the death of Sir Charles Scott Sherrington, O.M., G.B.E., F.R.S., at the ripe old age of 94, the world has lost one of its greatest scientists and one who contributed to ophthalmology, although incidentally, yet on a grand scale. Sherrington's scientific life was devoted mainly to the study of the central nervous system, the complexities of which were elucidated for the first time through his recognition that the simple spinal reflex was a unit which could be adequately studied by the experimental method. Advancing in this way from the simple to the complex and applying an experimental ingenuity which was unique with an industry and fertility of thought which were astonishing throughout a laboratory life of over fifty years, he synthesized into an integrated philosophy a subject which he had found in the early eighties of the nineteenth century a chaos of vague generalities. From the ophthalmological point of view, his crucial experiments on the reciprocal innervation of the ocular muscles and the perceptual processes involved in binocular vision will always remain fundamental landmarks in our knowledge. Nor were his life and activity confined to the laboratory: a philosopher and a poet of no mean order, an energetic man of affairs, an eminent public speaker, unspoiled by all the honours that Great Britain and the international world of science were proud to bestow upon him, he remained to the end one of the most endearing and modest of men.

LOUIS BRAILLE CENTENARY

The Royal Society of Arts held a special meeting on March 5, 1952, to commemorate the centenary of Louis Braille, who died on January 6, 1852. His Excellency the French Ambassador, M. René Massigli, G.C.V.O., K.B.E., was in the Chair. An appreciation of Louis Braille and his work for the blind was read by Vernon Barlow.